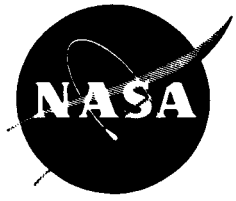
TESTING AND EVALUATION OF NICKEL-CADMIUM SPACECRAFT-TYPE CELLS

BY
I. F. LUKE
E. A. ROEGER



FINAL TECHNICAL REPORT

prepared for
GODDARD SPACE FLIGHT CENTER
CONTRACT NAS 5-1048

Inland Testing Laboratories
COOK ELECTRIC COMPANY

FOREWORD

The life-cycle tests and failure analysis of this cell testing and evaluation program are being continued under Contract No. NAS 5-9073.

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I. INTRODUCTION

The rapid advancement in the field of space exploration has put a tremendous demand on the battery method of storing electrical power. One of the more acceptable battery types for this application is the sealed, sintered plate, nickel-cadmium cell. Because of the continually changing applications, a wealth of information concerning the operation of the cells must be supplied to enable the cell designer and user to keep the performance of the cell abreast of these advancements.

The object of this program therefore, is to obtain information concerning the operation of the Sonotone 3.5 AH, Gould-National 3.5 AH, and Gulton 6 AH nickel-cadmium cells since the initiation of the contract to 1 July 1964. This information was afforded by subjecting the cell to a series of initial tests, a cycle-life test, and a post-test analysis. The initial tests, consisting of both mechanical and electrical, provide a basis of information for future comparison. The cycle-life test is used to simulate actual operating conditions while the post-test analysis provides information to be compared with the initial information for the purposes of determining the effects of the cycle-life test.

II. DISCUSSION

A. CELL DESCRIPTION

1. Sonotone 3.5 AH Cell

The Sonotone nickel-cadmium cell being evaluated under this program is rated as a 3.5 ampere-hour cell when discharged at a 5 hour rate to 1.0 volts. The positive electrode is made by impregnating a highly porous nickel plaque with a nickel salt solution while the negative electrode is made by impregnating the plaque with a cadmium salt solution. The porous nickel plaque was prepared by sintering a fine nickel powder to a woven nickel wire screen. The cell uses a treated absorbent cellulose for the separator system. The electrolyte used in the cell is a 30% solution of potassium hydroxide. The cell case has an outside diameter of approximately 1.33 inches and is approximately 2.38 inches high. The completed cell weighs approximately 5.5 ounces.

2. Gould-National 3.5 AH Cell

The Gould-National nickel-cadmium cell being evaluated under this program is rated as a 3.5 ampere-hour cell. The cell uses a positive electrode of NiOOH

impregnated into a sintered nickel plaque and a negative electrode of Cd also impregnated into a sintered nickel plaque. The positive electrode weighs approximately 16 grams while the negative electrode weighs approximately 28 grams. The cell uses Pellon 2505 as its separator system. The glass-to-metal seal is heli-arc welded to the pure nickel can. The electrolyte used in the cell is a 30% solution of KOH. The cell case has an outside diameter of approximately 1.28 inches and is approximately 2.24 inches high. The completed cell weighs approximately 135-140 grams.

3. Gulton 6.0 AH Cell

The Gulton Type VO-6HS sealed nickel-cadmium cell is rated at 6.0 ampere-hours when discharged at a 3.0 ampere rate to an endpoint voltage of 1.0 volts. The cell has 8 positive and 9 negative plates and uses a Dynel and Viskon separator system. The ceramic-to-metal seal, produced by the active metal process, was heli-arc welded to a deep drawn container. The cell dimensions are approximately 3.35 inches high without the terminals, 2.10 inches wide, and 0.825 inches thick. The finished cell weighs approximately 0.62 lbs.

B. INITIAL TESTS

Before subjecting the individual cells to the life cycle tests, they were subjected to a series of initial tests consisting of both mechanical and electrical measurements. A summary of the tests to which fifty (50) cells of each manufacturer were subjected is listed in Table 1, Table 2, and Table 3. To perform the electrical tests, the cells were electrically connected in groups of ten (10) cells each, unless otherwise specified or limited by the quantity of cells subjected to a test. If an individual cell failed during the initial tests, that cell was not subjected to the life cycle tests prior to cell failure analysis.

1. Visual and Mechanical

Each of the fifty (50) cells of the three (3) manufacturers, was visually inspected, upon receipt, for general workmanship, irregularities in construction, and evidence of damage or leakage. Measurements were taken of the weight, height, and greatest diameter of the cell cases for comparison purposes during the analysis which was conducted on the failed cells. At the conclusion of the visual and mechanical tests, the cells were washed and brushed thoroughly in distilled water

until a litmus paper test showed that there was no traces of electrolyte on the outside surfaces of the cell.

During the visual and mechanical inspection and measurements, no noticeable departure from the accepted standard conditions for the cells was noted.

2. Capacity

The initial electrical test performed on the test cells of each manufacturer was the capacity test. The cells were charged at a rate of C/10 for a period of 16 hours, allowed to stand on open circuit conditions for a period of one (1) hour and then discharged at a rate of C/2 ampere to a cutoff voltage of 1.0 volt. This charge-discharge cycle was repeated until a total of three (3) cycles had been completed. During the third cycle, the end of charge voltage was measured and recorded, the voltage after one (1) hour of discharge was measured and recorded, and the ampere-hour capacity of the cell was measured and recorded.

After subjecting a portion of the Gulton cells to the aforementioned capacity test, some of the cells had a high end-of-charge voltage and a below-average capacity. In an attempt to increase the capacity output, additional

capacity tests using other charge rates and procedures were established. Each of the cells was not subjected to the entire series of capacity tests, but some cells were subjected to more than three (3) capacity test cycles in the series as may be noted in Table 6. The tests used for determining the capacity of the cells were as follows:

Test A - The cells were charged at a rate of C/10 ampere for a period of 16 hours, allowed to stand on open circuit conditions for a period of 1 hour and then discharged at a rate of C/2 amperes to a cutoff voltage of 1.0 volt.

Test B -Same as Test A.

Test C -Same as Test A.

Test D - The cells were charged at a rate of C/20 ampere for a period of 41.5 hours, then charged at a rate of C/10 ampere for a period of 6 hours, and finally charged at the rate of C/20 ampere for an additional 66 hours. After the cells were allowed to stand on open circuit condition for a

period of 1 hour, they were discharged at a rate of C/2 amperes to a cutoff voltage of 1.0 volt.

Test E - Same as Test A.

Test F - The cells were charged at a rate of C/5 amperes for a period of 1.5 hours, allowed to stand on open-circuit conditions for a period of 1 hour, and then discharged at a rate of C/2 ampere for a period of 30 minutes. This procedure was repeated for 24 cycles after which Test A was repeated.

Test G - The cells were subjected to 34 additional cycles of Test F after which Test A was repeated.

Test H - The cells were charged at a rate of C/24 ampere for a period of 64 hours, off for a period of 96 hours, charged again at a rate of C/24 ampere for a period of 24 hours, then subjected to a constant voltage charge of 1.45 volts per cell for a period of 3 hours, and finally charged at a rate of C/10

ampere for a period of 16 hours. After the cells were allowed to stand on open circuit conditions for a period of 1 hour, the cells were discharged at a rate of C/2 ampere to a cutoff voltage of 1.0 volt.

Test I - The cells were subjected to a constant voltage charge of 1.45 volts per cell for a period of 3 hours and then charged at a rate of C/10 ampere for a period of 16 hours. After the cells were allowed to stand on open circuit conditions for a period of 1 hour, the cells were discharged at a rate of C/2 amperes to a cutoff voltage of 1.0 volt.

Test J - Same as Test I.

Test K - Same as Test I.

Test L - The cells were subjected to a constant voltage charge of 1.45 volts per cell for a period of 3 hours, allowed to stand on open circuit conditions for a period of 1 hour, and then discharged at a rate of C/2 amperes to a cutoff voltage of 1.0 volt.

Tables 4, 5, and 6 list the capacity data for the Sontone, Gould-National and Gulton cells respectively. The tables list the end of charge voltage, voltage after one (1) hour of discharge, and the ampere-hour capacity of the cell. In addition, Table 6 indicates to which tests in the series the Gulton cells were subjected.

3. Electrical Leakage

At the conclusion of the capacity test, all the discharged cells were shorted for a period of 16 hours and then allowed to stand on open circuit for a period of 24 hours. During this latter period, the terminal voltage of the cells was monitored periodically to note any change in the open-circuit terminal voltage. If the terminal voltage of a cell was below 1.0 volt at the end of the 24 hour period, the cell was charged at a rate of C/5 ampere for a period of five (5) minutes and then allowed to stand in an open-circuit condition for a period of 24 hours. If a cell did not have an open-circuit terminal voltage of 1.2 volts at the end of the 24 hour stand period, it was considered a "failed cell".

The results of the electrical leakage test for the Sonotone, Gould-National, and Gulton cells are shown

in Tables 7, 8, and 9 respectively. Two (2) cells of each of the three (3) manufacturers failed to have the required terminal voltage of 1.2 volts after the five (5) minute charge followed by the 24 hour stand period. The cells which failed were the Sonotone Cells No. R44 and R58, Gould-National Cells No. 13 and No. 14, and the Gulton Cells No. 643 and No. 770.

4. Overcharge

To equalize the electrical charge of the cells and condition them for the overcharge test, each of the test cells was charged at a rate of C/10 ampere for a period of 16 hours. To establish a steady state charging voltage, the cells were overcharged at a rate of C/5 ampere for a minimum of 48 hours or until there was a change in the cell voltage of less than 10 mv per day. A steady state overcharge voltage was likewise established at a C/10 ampere charging rate and a C/20 ampere charging rate.

The results of the overcharge tests for the Sonotone, Gould-National and Gulton Cells are listed in Tables 10, 11, and 12 respectively. These tables list the results for the C/5 ampere, C/10 ampere, and C/20 ampere charging rates.

5. Internal Resistance

Each of the test cells was subjected to an internal resistance test. With the cells fully charged from the overcharge test, each cell was placed on discharge at a rate of C/20 ampere. As soon as the terminal voltage stabilized at this rate, the cell was given a short discharge pulse at a rate of C ampere. The terminal voltage of the cell (V_1) immediately prior to the short discharge pulse and the terminal voltage of the cell (V_2) five (5) milliseconds after the cell was subjected to the discharge pulse, were measured and recorded with a sensitive oscillograph. The internal resistance of the cell was then calculated by using the formula:

$$R = \frac{V_1 - V_2}{I_C - I_{C/20}}$$

The results of the calculations for the Sonotone, Gould-National, and Gulton cells are listed in Tables 13, 14, and 15 respectively.

6. Electrolyte Leakage

At the completion of the previously mentioned electrical tests, each cell case was rubbed with a wet piece of litmus paper to determine if electrolyte had escaped

from the cell case. If electrolyte was present on the case, it would have been indicated by a change in the litmus paper from red to blue.

Since the leakage of some cells tested according to the above mentioned procedure was doubtful, these cells were subjected to a second leakage test. The cells were fully discharged at a rate of C/2 ampere and then recharged at a C/10 ampere rate for a minimum of 15 hours. The cells were then immersed in a container of distilled water which was placed under a bell-jar. The absolute pressure of the air above the water was reduced to one (1) inch of mercury and maintained for a period of one (1) minute, or until air bubbles ceased to be given off by the water. The absolute pressure was then increased to 2 1/2 inches of mercury. The cell was considered as leaking if bubbles were coming from within the cell case. However, bubbles which were the results of entrapped air on the various exterior parts of the case were not considered as contributing to the leakage of the cell.

There were four (4) Sonotone cells which showed leakage as a result of the electrolyte leakage test. These

four (4) cells were the Cells No. 62, No. 73, No. R37, and No. R54. Each of these cells showed leakage at the weld where the top is joined to the cylindrical body.

Twenty-three (23) Gould-National cells showed evidence of leakage as a result of the electrolyte leakage test. The leakage was around the center (positive) terminal on all cells except one (1) where the leakage was at the side of the case. At the request of NASA/ GSFC Technical Representatives, the failed cells were returned to the manufacturer who inspected each of them for the extent of damage. The manufacturer's inspection showed that the cells had no electrical damage so they were returned to Inland Testing Laboratories and subjected to the cycle-life tests.

There were five (5) Gulton cells which showed leakage as a result of the electrolyte leakage test. Cells No. 607 and No. 645 showed leakage around the filler tube while cells No. 657, No. 810, and No. 830 showed leakage around the positive terminal.

7. Vibration

Five (5) fully charged cells from each of the manufacturers were selected at random, and were then

subjected to a sinusoidal vibration test as specified in the NASA Preliminary Specification entitled "Environmental Exposurers and Tests for Subassemblies of International Ionosphere Satellite S-51", dated February 7, 1961. The test cells were mounted in a rigid test fixture which, in turn, was attached to the table of the vibration machine. The acceleration was monitored by means of an accelerometer rigidly attached on the fixture near the test samples.

The test samples were subjected to the sinusoidal vibration test according to the following sweep schedule:

Sinusoidal Sweep Schedule

Frequency Range, cps	Test Duration Minutes	Acceleration g's, 0-to-peak
5-50	1.66	2.3
50-500	1.66	10.7
500-2000	1.00	21.0
2000-3000	0.36	54.0
3000-3500	0.30	21.0

The applied frequency was swept from 5 to 3500 cps once in each of the cells mutually perpendicular axes. The frequency sweep in each axis took approximately five (5) minutes for a total vibration time of 15 minutes.

During the applied vibration, the test cells were

discharged at a C/5 ampere rate while the discharge currents and terminal voltages were monitored for evidence of cell malfunction. Upon completion of the vibration test, the cells were visually examined for evidence of mechanical damage and checked for electrolyte leakage as specified in Part 6 of this section. There were no failures as a result of the vibration test.

8. Shock

Five (5) fully charged cells from each of the manufacturers were randomly selected from those cells not subjected to the vibration test and were then subjected to a shock test as specified in Procedure V of MIL-E-5272C. The test cells were mounted in a rigid test fixture which, in turn, was mounted to the shock machine.

Each test cell was subjected to 18 impact shocks of 40 g acceleration, with each shock impulse having a time duration of 11 ± 1 milliseconds. Three (3) shocks were applied in each of the three (3) mutually perpendicular axis of the cell.

During the shock test, the cells were discharged at a C/5 ampere rate with the discharge current and

terminal voltage monitored at the moment of impact for evidence of malfunction in the cell. At the conclusion of the test, the test samples were visually examined for mechanical damage and checked for electrolyte leakage as specified in Part 6 of this section. There were no failures as a result of the shock test.

9. Acceleration

Five (5) fully charged cells from each of the manufacturers were randomly selected from those cells not subjected to the vibration or shock tests and were then subjected to an acceleration test as specified in the NASA Preliminary Specification entitled "Environmental Exposurers and Test for Subassemblies of International Ionosphere Satellite S-51", dated February 7, 1961. The test cells were mounted in a rigid fixture which, in turn, was mounted to a centrifuge table.

The test cells were subjected to the following sequence of acceleration exposures in the order listed:

Axis Direction	Acceleration Gravity Units (g)	Duration Min.
+Z	28.0	5.0
± Y, +X	4.0	3.0
-X	12.0	0.5

The specified acceleration was that experienced by the center of geometry of the test cell.

During the acceleration test, the cells were discharged at a C/5 ampere rate with the discharge current and terminal voltage monitored for evidence of cell malfunction. At the conclusion of the acceleration test, the cells were visually examined for mechanical damage and checked for electrolyte leakage as specified in Part 6 of this section. There were no failures as a result of the acceleration test.

C. CYCLE-LIFE TESTS

The cells, except those which failed during the initial tests, from each manufacturer were subjected to cycle-life tests employing 100 minute charge-discharge periods consisting of 60 minutes of charge and 40 minutes of discharge. The cycle-life tests were performed at three (3) ambient temperatures and three (3) depths of discharge unless limited by the number of acceptable cells of a manufacturer.

Before subjecting the cells to the cycle-life tests, five (5) cells from each manufacturer were chosen to be subjected to a series of preliminary tests at the discharge rates and cycle periods to be used in the cycle-life tests. These preliminary tests were performed in an attempt to determine an adequate percent overcharge and the maximum allowable cell charging voltage without causing excessive gassing or overcharging at each of the three (3) cycle-life temperature environments. The nominal rated capacity of the cells was used for determining the discharge rates at each depth of discharge. As a result of the preliminary tests, it was decided to vary the percent of ampere-hours replaced during the 60 minute charge period with the temperature environment in which the group would be cycle-life tested,

but to use the same percentage for cells of different manufacturer and for the three (3) depths of discharge at the one temperature environment. The charging rates were set to replace 115% of the removed ampere-hours at -10°C, 125% of the removed ampere-hours at 25°C, and 150% of the removed ampere-hours at 50°C.

Upon completion of the preliminary tests, the cells were separated into their respective cycle-life test groups. The cells of a group, consisting of like cells from the same manufacturer, were electrically connected in series. Cells which had been subjected to the vibration, shock, or acceleration tests were electrically connected to those cells which had not been subjected to these tests. In this manner, a correlation of the test results may be made with respect to the extent of cell degradation, if any, caused by the environmental test conditions.

In order to assure fully charged cells for the beginning of the cycle-life tests, each cell was first discharged at a C/2 ampere rate to an endpoint of 1.0 volt and then recharged at a C/5 ampere rate for a period of eight (8) hours. Upon completion of the eight (8) hour charge period, each cell was placed in its respective test temperature environment.

Immediately upon stabilization of a cell group at its test temperature, the cycle-life tests were begun.

All charges and discharges being employed in the cycle-life tests are constant current unless during charge a cell groups voltage reaches the limiting voltage established for that group. In this case, the charge equipment automatically switches to a constant voltage mode and charging for the remainder of the 60 minute period is accomplished with constant voltage at the established limiting voltage value. The limiting voltages were determined from the preliminary tests.

Unless otherwise specified, cycle-life tests will continue uninterrupted until one half of the original cells in a group fail. A cell is considered to have failed when its terminal voltage falls below 1.0 volt during the 40 minute discharge period. However, a cell is not removed from the group until it consistently exhibits this depletion on subsequent cycle(s). This process of determining a failure is employed to prevent premature classification of a cell as a failure as a result of one weak discharge which may, if permitted, be followed by a considerable number of satisfactory discharges.

1. Sonotone Cells

Forty-four (44) Sonotone Cells, which satisfactorily completed the initial tests, were subjected to the cycle-life tests. These cells were separated into four (4) groups of ten (10) cells each and one (1) group of four (4) cells. The groups were tested at three (3) ambient temperatures (-10°C, 25°C, and 50°C) and three (3) depths of discharge (10%, 25%, and 40%).

The charging rates and limiting voltages, determined from the preliminary tests, along with the discharging rates being used during the cycle-life tests are as follows:

Cycle-Life Condition	Charging Rate (amps.)	Discharging Rate (amps.)	Limiting Voltage
10% Discharge at -10°C	0.405	0.525	1.54 volts/cell
10% Discharge at 25°C	0.438	0.525	1.50 volts/cell
10% Discharge at 50°C	0.525	0.525	None
25% Discharge at 25°C	1.090	1.310	1.50 volts/cell
40% Discharge at 25°C	1.750	2.100	1.50 volts/cell

After the charge period of the 3297th cycle, the cells cycled at the 40% depth of discharge were removed from cycling and the residual capacity of each cell was checked. The capacity of Cell No. 57 was 2.1 AH, of Cell No. 58 was 2.69 AH, and of Cell No. 59 was 2.75 AH. After three (3) charge-discharge cycles with a

constant potential charge at 1.45 volts, the capacity of Cells No. 57, No. 58, and No. 59 was 3.40 AH, 3.45 AH, and 3.66 AH respectively. The cells were then returned to their cycle-life testing at 40% depth of discharge where they remained until failure.

The end-of-charge and end-of-discharge voltages for each group were continuously monitored with the results being recorded periodically throughout the cycle-life tests. These results along with the end-of-charge and discharge voltages for individual cells selected at random from each group are presented in Figures 1 through 5 and 6 through 14 respecitvely. Figures 15 through 23 show the entire charge-discharge voltage measurements for representative cycles of the cells selected from each group.

Two (2) groups have failed as a result of the cycle-life tests at the end of this report period. These groups are the ones cycling at 50°C with a 10% depth of discharge and 25°C with a 40% depth of discharge. Although the test group cycle-life tested at 50°C with a 10% depth of discharge failed after 5545 cycles, the cycle-life tests were continued under the same conditions

inorder to obtain additional information concerning cells operating at the 50°C environment. As the remaining cells in the group failed, they were analyzed as failed cells.

The 15 cells, which had failed the cycle-life tests at the end of this reporting period, are listed below according to their cycling conditions:

Cycling Condition	Cell Number	Cycles Completed
10% Discharge at 50°C	63	3288
	67	6195
	69	4008
	70	5545
	71	5031
	75	4234
	R45	7175
	R46	5100
	R47	7175
	R48	7175
25% Discharge at 25°C	R56	7811
40% Discharge at 25°C	56	537
	57	6146
	58	6146
	59	6146

Upon removal from the cycling groups, each of these failed cells were subjected to the failure analysis to determine the type of failure.

2. Gould-National Cells

Forty (40) Gould-National Cells, which were deem acceptable for life-cycling after the initial tests, were subjected to the cycle-life tests. These cells were separated into three (3) groups of ten (10) cells each and two (2) groups of five (5) cells each. The groups were tested at three (3) ambient temperatures (-10°C, 25°C, and 50°C) and three (3) depths of discharge (10%, 25%, and 40%).

The charging rates and limiting voltages, determined from the preliminary tests, along with the discharging rates being used during the cycle-life tests are as follows:

Cycle-Life Condition	Charging Rate (amps.)	Discharging Rate (amps.)	Limiting Voltage
10% Discharge at -10°C	0.405	0.525	1.54 volts/cell
10% Discharge at 25°C	0.438	0.525	1.50 volts/cell
10% Discharge at 50°C	0.525	0.525	None
25% Discharge at 25°C	1.090	1.310	1.52 volts/cell
40% Discharge at 25°C	1.750	2.100	1.54 volts/cell

The end-of-charge and end-of-discharge voltages for each group were continuously monitored with the results being recorded periodically throughout the cycle-life tests. These results along with the end-of-charge

and discharge voltages for individual cells selected at random from each group are presented in Figures 24 through 28 and 29 through 36 respectively. Figures 37 through 44 show the entire charge-discharge voltage measurements for representative cycles of the cells selected from each group.

Three groups have failed as a result of the cycle-life tests at the end of this report period. The cycle-life conditions and the number of cycles completed before failure for each of these groups is listed below:

Cycling Condition	Cycles Completed
10% discharge at 50°C	3576
25% discharge at 25°C	5110
40% discharge at 25°C	1282

Although the test group cycle-life tested at 50°C with a 10% depth of discharge failed after 3576 cycles, the cycle-life tests were continued under the same conditions inorder to obtain additional information concerning cells operating at the 50°C environment. As the remaining cells in the group failed, they were analyzed as failed cells.

The 17 cells, which had failed the cycle-life tests at the end of this report period,are listed below according

to their cycling conditions:

Cycling Condition	Cell Number	Cycles Completed
10% Discharge at 50°C	20	2973
	21	2668
	23	5536
	28	7101
	32	7348
	33	7849
	36	3372
	41	3216
	42	3576
25% Discharge at 25°C	5	5110
	7	2487
	13	4608
	37	2487
	39	5110
40% Discharge at 25°C	43	1282
	46	864
	50	864

Upon removal from the cycling groups, each of these failed cells was subjected to the failure analysis to determine the type of failure.

3. Gulton Cells

Forty (40) Gulton Cells, which satisfactorily completed the initial tests, were subjected to the cycle-life tests. These cells were separated into four (4) groups of ten (10) cells each. The groups were tested at three (3) ambient temperatures (-10°C, 25°C, and

50°C) and two (2) depths of discharge (10% and 25%).

The charging rates and limiting voltages, determined from the preliminary tests, along with the discharging rates being used during the cycle-life tests are as follows:

Cycle-Life Condition	Charging Rate (amps.)	Discharging Rate (amps.)	Limiting Voltage
10% Discharge at -10°C	0.690	0.900	1.54 volts/cell
10% Discharge at 25°C	0.750	0.900	1.50 volts/cell
10% Discharge at 50°C	0.900	0.900	None
25% Discharge at 25°C	1.880	2.225	1.50 volts/cell

The end-of-charge and end-of-discharge voltages for each group were continuously monitored with the results being recorded periodically throughout the cycle-life tests. These results along with the end-of-charge and discharge voltages for individual cells selected at random from each group are presented in Figures 45 through 48 and 49 through 56 respectively. Figures 57 through 64 show the entire charge-discharge voltage measurements for representative cycles of the cells selected from each group.

Eight cells have failed as a result of the cycle-life tests at the end of this report period. These cells and the number of cycles successfully completed before failure are listed below according to condition:

Cycling Condition	Cell Number	Cycles Completed
10% Discharge at 25°C	638	7098
	829	2263
10% Discharge at 50°C	610	5632
	611	7531
	624	8456
25% Discharge at 25°C	656	1298
	813	1270
	814	1416

Upon removal from the cycling groups, each of these eight cells was subjected to the failure analysis to determine the cause or causes of failure.

D. FAILURE ANALYSIS

When a cell fails during the cycle-life tests, the failed cell is removed from its test conditions and allowed to stabilize at room temperature and open-circuit conditions for a period of at least 24 hours. The cells are visually inspected externally for evidence of case leakage, case distortion, seal leakage, terminal damage or other deterioration. The cell weight and dimensional measurements, initially performed during the Visual and Mechanical Tests (see 1, Part B of this Section), is repeated. Post-failure capacity and post-failure open-circuit stand tests are performed.

These data are then correlated with the charge-discharge characteristics, cycle-life test parameters, precycle-life test data, and all manufacturing data available, to detect any changes, physical or performance, that can be interpreted as leading to failure or degradation to the cell. It is then determined what other electrical measurements or tests are warranted to aid in determining the cause(s) of cell failure. The tests are selected and performed so as to minimize additional deterioration of the cell while the sequence is such that each test will have a minimum effect upon the

results of subsequent tests or measurements.

A summary of the results obtained from the failure analysis tests conducted on the Sonotone, Gould-National, and Gulton cells which have failed the cycle-life tests to date, is shown in Tables 16, 17, and 18 respectively.

III. CONCLUSIONS

Before a complete evaluation of the test cells can be performed, additional failures will have to occur. At the end of this reporting period, only approximately 33% of the test cells had failed. There has been no failures of those cells operating at -10°C with a 10% depth of discharge and only two (2) cells have failed at 25°C with a 10% depth of discharge.

Six (6) Sonotone cells failed during the initial testing. Two (2) of these cells failed the electrical leakage while the other four (4) showed a degree of electrolyte leakage sufficient to classify them as failures. Twenty-five (25) Gould-National cells were considered as failing the initial tests. Two (2) of these cells failed the electrical leakage while the other twenty-three (23) showed various degrees of electrolyte leakage. Seven (7) Gulton cells failed the initial testing. Two (2) of these cells failed during the electrical leakage test while the other 5 failed the electrolyte leakage test.

The capacity tests revealed some statistics concerning the actual ampere-hour capacity of the cells as compared to the manufacturer's rated capacity. The tests on the Sonotone (3.5 AH) cells showed that 34% of the cells had a

capacity between 3.4 and 3.6 ampere-hours, 46% between 3.4 and 3.8 ampere-hours, 56% between 3.2 and 3.8 ampere-hours and 80% between 3.2 and 4.0 ampere-hours. The tests on the Gould-National (3.5 AH) cells showed that 20% of the cells had a capacity between 3.4 and 3.6 ampere-hours, 66% between 3.4 and 3.8 ampere-hours, and 90% between 3.4 and 4.0 ampere-hours. The tests on the Gulton (6 AH) cells showed that 30% of the cells had a capacity between 5.8 and 6.2 ampere-hours, 50% between 5.6 and 6.4 ampere-hours, and 68% between 5.2 and 6.6 ampere-hours.

There were no cell failures of any of the three (3) manufacturers as a result of the requirements imposed upon them by the vibration, shock, or acceleration tests. The cells operated quite normally during and after each of these tests.

No significant conclusions can be made concerning the cycle-life tests at the end of this reporting period because of the limited number of cell failures. However certain trends have become apparent as the cycle-life tests progress. Generally, the number of cycles successfully completed before failure is dependent upon both the temperature environment and depth of discharge. Under the test parameters at which this program was performed the temperature appears to be the more predominate.

TABLE 1 - SUMMARY OF INDIVIDUAL CELL TESTS
SONOTONE CELLS

Cell No.	Visual & Mech.	Capacity	Electrical Leakage	Over-Charge	Inter. Resis.	Electrolyte Leakage	Vib.	Shock	Accel.	Cycling Group*
51	X	X	X	X	X	X	X			A
52	X	X	X	X	X	X	X			A
53	X	X	X	X	X	X	X			A
54	X	X	X	X	X	X	X			A
55	X	X	X	X	X	X	X			A
56	X	X	X	X	X	X				E
57	X	X	X	X	X	X				E
58	X	X	X	X	X	X				E
59	X	X	X	X	X	X				E
60	X	X	X	X	X	X				D
61	X	X	X	X	X	X				D
62	X	X	X	X	X	X		X		
63	X	X	X	X	X	X			X	C
64	X	X	X	X	X	X		X		B
65	X	X	X	X	X	X		X		B
66	X	X	X	X	X	X		X		B
67	X	X	X	X	X	X			X	C
68	X	X	X	X	X	X		X		B
69	X	X	X	X	X	X			X	C
70	X	X	X	X	X	X			X	C
71	X	X	X	X	X	X			X	C
72	X	X	X	X	X	X				
73	X	X	X	X	X	X				A
74	X	X	X	X	X	X				B
75	X	X	X	X	X	X				C

Note:

* A - 10% Discharge at -10°C
  B - 10% Discharge at 25°C
  C - 10% Discharge at 50°C
  D - 25% Discharge at 25°C
  E - 40% Discharge at 25°C

TABLE 1 (Cont'd) - SUMMARY OF INDIVIDUAL CELL TESTS
SONOTONE CELLS

Cell No.	Visual & Mech.	Capacity	Electrical Leakage	Over-Charge	Inter. Resis.	Electrolyte Leakage	Vib.	Shock	Accel.	Cycling Group*
R34	X	X	X	X	X	X				A
R35	X	X	X	X	X	X				A
R36	X	X	X	X	X	X				A
R37	X	X	X	X	X	X				
R38	X	X	X	X	X	X				A
R39	X	X	X	X	X	X				B
R40	X	X	X	X	X	X				B
R41	X	X	X	X	X	X				B
R42	X	X	X	X	X	X				B
R43	X	X	X	X	X	X				B
R44	X		X	X	X	X				
R45	X	X	X			X				C
R46	X	X	X	X	X	X				C
R47	X	X	X	X	X	X				C
R48	X	X	X	X	X	X				C
R49	X	X	X	X	X	X				D
R50	X	X	X	X	X	X				D
R51	X	X	X	X	X	X				D
R52	X	X	X	X	X	X				D
R53	X	X	X	X	X	X				D
R54	X	X	X	X	X	X				
R55	X	X	X	X	X	X				D
R56	X	X	X	X	X	X				D
R57	X	X	X	X	X	X				D
R58	X		X			X				

Note:

* A - 10% Discharge at -10°C
B - 10% Discharge at 25°C
C - 10% Discharge at 50°C
D - 25% Discharge at 25°C
E - 40% Discharge at 25°C

TABLE 2 - SUMMARY OF INDIVIDUAL CELL TESTS
GOULD-NATIONAL CELLS

Cell No.	Visual & Mech.	Capacity	Electrical Leakage	Over-Charge	Inter. Resis.	Electrolyte Leakage	Vib.	Shock	Accel.	Cycling Group*
1	X	X	X	X	X	X				B
2	X	X	X	X	X	X				
3	X					X				D
4	X	X	X	X	X	X				
5	X	X	X	X	X	X				D
6	X	X	X	X	X	X	X			B
7	X	X	X	X	X	X				D
8	X	X	X	X	X	X				B
9	X	X	X	X	X	X			X	B
10	X	X	X	X	X	X	X			B
11	X	X	X	X	X	X				D
12	X	X	X	X	X	X	X			B
13	X	X	X			X				D
14	X	X	X	X	X	X				B
15	X	X	X	X	X	X			X	B
16	X	X	X	X	X	X				D
17	X	X	X	X	X	X				
18	X	X	X	X	X	X				
19	X	X	X	X	X	X				
20	X	X	X	X	X	X			X	C
21	X	X	X	X	X	X			X	C
22	X	X	X	X	X	X	X			B
23	X	X	X	X	X	X			X	C
24	X	X	X	X	X	X	X			B
25	X	X	X	X	X	X				A

Note:

* A - 10% Discharge at -10°C
B - 10% Discharge at 25°C
C - 10% Discharge at 50°C
D - 25% Discharge at 25°C
E - 40% Discharge at 25°C

TABLE 2 (Cont'd) - SUMMARY OF INDIVIDUAL CELL TESTS
GOULD-NATIONAL CELLS

Cell No.	Visual & Mech.	Capacity	Electrical Leakage	Over-Charge	Inter. Resis.	Electrolyte Leakage	Vib.	Shock	Accel.	Cycling Group*
26	X	X	X	X	X	X				A
27	X	X	X	X	X	X				A
28	X	X	X	X	X	X		X		C
29	X	X	X	X	X	X		X		
30	X	X	X	X	X	X				D
31	X	X	X	X	X	X		X		C
32	X	X	X	X	X	X				C
33	X	X	X	X	X	X		X		C
34	X	X		X	X	X				
35	X	X	X	X	X	X				A
36	X	X	X	X	X	X		X		C
37	X	X	X	X	X	X				D
38	X	X	X	X	X	X				A
39	X	X	X	X	X	X				D
40	X	X	X			X				D
41	X	X	X	X	X	X				C
42	X	X	X	X	X	X				C
43	X	X	X	X	X	X				E
44	X	X	X	X	X	X				
45	X	X	X	X	X	X				E
46	X	X	X	X	X	X				E
47	X	X	X	X	X	X				
48	X	X	X	X	X	X				
49	X	X	X	X	X	X				E
50	X	X	X	X	X	X				E

Note:

* A - 10% Discharge at -10°C
B - 10% Discharge at 25°C
C - 10% Discharge at 50°C
D - 25% Discharge at 25°C
E - 40% Discharge at 25°C

TABLE 3 - SUMMARY OF INDIVIDUAL CELL TESTS
GULTON CELLS

Cell No.	Visual & Mech.	Capacity	Electrical Leakage	Over-Charge	Inter. Resis.	Electrolyte Leakage	Vib.	Shock	Accel.	Cycling Group*
602	X	X	X	X	X	X				C
604	X	X	X	X	X	X				C
607	X	X	X	X	X	X				
610	X	X	X	X	X	X				C
611	X	X	X	X	X	X				C
615	X	X	X	X	X	X				C
617	X	X	X	X	X	X				A
619	X	X	X	X	X	X				A
620	X	X	X	X	X	X				A
623	X	X	X	X	X	X				A
624	X	X	X	X	X	X			X	C
627	X	X	X	X	X	X				A
628	X	X	X	X	X	X				B
631	X	X	X	X	X	X	X			A
634	X	X	X	X	X	X				
638	X	X	X	X	X	X				B
644	X	X	X	X	X	X				B
645	X	X	X	X	X	X				
647	X	X	X	X	X	X				B
648	X	X	X	X	X	X				B
653	X	X	X	X	X	X				B
654	X	X	X	X	X	X				
656	X	X	X	X	X	X				D
657	X	X	X	X	X	X				
660	X	X	X	X	X	X				D

Note: * A - 10% Discharge at -10°C
B - 10% Discharge at 25°C
C - 10% Discharge at 50°C
D - 25% Discharge at 25°C

TABLE 3 (Cont'd) - SUMMARY OF INDIVIDUAL CELL TESTS
GULTON CELLS

Cell No.	Visual & Mech.	Capacity	Electrical Leakage	Over-Charge	Inter. Resis.	Electrolyte Leakage	Vib.	Shock	Accel.	Cycling Group*
661	X	X	X	X	X	X				D
719	X	X	X	X	X	X			X	C
765	X	X	X	X	X	X			X	C
770	X	X	X	X	X	X				
778	X	X	X	X	X	X			X	C
779	X	X	X	X	X	X			X	C
780	X	X	X	X	X	X	X			A
783	X	X	X	X	X	X	X			A
798	X	X	X	X	X	X	X			A
801	X	X	X	X	X	X	X			A
804	X	X	X	X	X	X				D
810	X	X	X	X	X	X				
812	X	X	X	X	X	X				D
813	X	X	X	X	X	X				D
814	X	X	X	X	X	X				D
815	X	X	X	X	X	X				
816	X	X	X	X	X	X				D
818	X	X	X	X	X	X				D
820	X	X	X	X	X	X				D
822	X	X	X	X	X	X		X		B
825	X	X	X	X	X	X		X		B
826	X	X	X	X	X	X				
827	X	X	X	X	X	X		X		B
829	X	X	X	X	X	X		X		B
830	X	X	X	X	X	X		X		

Note:

* A - 10% Discharge at -10°C
B - 10% Discharge at 25°C
C - 10% Discharge at 50°C
D - 25% Discharge at 25°C

TABLE 4 - CAPACITY TEST RESULTS
SONOTONE CELLS

Cell No.	Capacity		
	End of Charge Voltage	Voltage After 1 Hr. Discharge	Capacity Ampere-Hours
51	1.40	1.18	3.18
52	1.44	1.15	3.03
53	1.41	1.16	3.53
54	1.41	1.16	3.73
55	1.41	1.19	3.88
56	1.40	1.19	3.56
57	1.44	1.10	3.38
58	1.42	1.15	3.44
59	1.41	1.17	3.21
60	1.41	1.17	3.56
61	1.41	1.18	3.38
62	1.40	1.19	3.34
63	1.41	1.19	3.73
64	1.40	1.20	3.87
65	1.41	1.17	3.87
66	1.41	1.20	3.82
67	1.42	1.19	3.52
68	1.41	1.19	3.99
69	1.41	1.19	3.52
70	1.44	1.13	3.41
71	1.40	1.18	3.41
72	1.41	1.19	3.96
73	1.41	1.19	3.47
74	1.41	1.18	3.43
75	1.41	1.18	3.87

Cell No.	Capacity		
	End of Charge Voltage	Voltage After 1 Hr. Discharge	Capacity Ampere-Hours
R34	1.40	1.20	2.49
R35	1.40	1.21	2.91
R36	1.40	1.20	2.63
R37	1.40	1.20	2.42
R38	1.40	1.20	2.77
R39	1.41	1.21	3.20
R40	1.41	1.22	3.45
R41	1.40	1.19	3.82
R42	1.41	1.19	3.90
R43	1.41	1.13	3.47
R44			
R45	1.41	1.14	3.59
R46	1.41	1.20	3.94
R47	1.41	1.19	3.82
R48	1.41	1.19	3.62
R49	1.40	1.20	3.48
R50	1.41	1.12	3.50
R51	1.41	1.21	3.83
R52	1.41	1.21	3.55
R53	1.41	1.21	3.68
R54	1.43	1.16	3.41
R55	1.41	1.20	3.76
R56	1.42	1.18	3.71
R57	1.43	1.09	3.17
R58			

TABLE 5 - CAPACITY TEST RESULTS
GOULD-NATIONAL CELLS

Cell No.	Capacity		
	End of Charge Voltage	Voltage After 1 Hr. Discharge	Capacity Ampere-Hours
1	1.44	1.24	3.88
2	1.45	1.23	3.68
3			
4	1.45	1.24	3.76
5	1.44	1.24	3.79
6	1.46	1.24	3.73
7	1.46	1.22	3.62
8	1.44	1.24	3.79
9	1.47	1.24	3.88
10	1.46	1.23	3.44
11	1.44	1.24	3.79
12	1.45	1.25	3.41
13	1.46	1.24	3.97
14	1.46	1.24	3.82
15	1.44	1.24	3.28
16	1.44	1.24	3.65
17	1.46	1.23	3.44
18	1.46	1.23	3.53
19	1.47	1.24	3.70
20	1.46	1.23	3.50
21	1.44	1.23	3.50
22	1.46	1.24	4.03
23	1.46	1.24	3.73
24	1.44	1.24	3.63
25	1.43	1.24	3.82

Cell No.	Capacity		
	End of Charge Voltage	Voltage After 1 Hr. Discharge	Capacity Ampere-Hours
26	1.44	1.24	3.91
27	1.46	1.24	3.79
28	1.46	1.24	3.91
29	1.44	1.23	3.73
30	1.44	1.24	3.82
31	1.46	1.23	3.76
32	1.46	1.24	4.06
33	1.46	1.24	3.91
34	1.44	1.21	3.27
35	1.46	1.24	3.88
36	1.45	1.23	3.59
37	1.44	1.24	3.76
38	1.44	1.24	3.79
39	1.44	1.24	3.64
40	1.45	1.24	3.91
41	1.45	1.22	3.76
42	1.44	1.23	3.62
43	1.44	1.23	3.65
44	1.44	1.24	3.67
45	1.43	1.22	3.91
46	1.44	1.23	3.56
47	1.44	1.23	3.70
48	1.44	1.23	3.56
49	1.45	1.23	3.62
50	1.44	1.23	3.53

TABLE 6 - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST A			TEST B			TEST C		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
602	1.47	1.24	6.27		1.24	6.45	1.45	1.24	6.06
604	1.56	1.24	5.40		1.24	5.37	1.43	1.23	5.07
607	1.47	1.25	6.35		1.25	6.67	1.45	1.25	6.30
610	1.56	1.24	5.15		1.24	5.32	1.44	1.23	5.12
611	1.57	1.25	5.50		1.25	5.57	1.45	1.24	5.25
615	1.48	1.25	6.20		1.25	6.27	1.44	1.24	5.85
617	1.55	1.24	5.30		1.24	5.30	1.43	1.23	5.00
619	1.52	1.25	6.60		1.25	6.97	1.47	1.25	6.77
620	1.49	1.25	6.25		1.25	6.37	1.45	1.25	6.04
623	1.56	1.24	5.10		1.24	4.90	1.46	1.23	4.65
624			*			*			*
627	1.56	1.24	5.13	1.52	1.23	4.97	1.45	1.23	4.69
628	1.52	1.22	4.48	1.46	1.22	4.35	1.42	1.22	4.25
631	1.57	1.25	5.70	1.54	1.25	5.63	1.43	1.25	5.33
634			*			*			*
638	1.48	1.25	6.95	1.48	1.25	7.07	1.45	1.25	6.79
644	1.47	1.25	6.77	1.47	1.25	6.43	1.44	1.25	5.98
645	1.58	1.25	5.57	1.53	1.24	5.50	1.45	1.24	5.24
647	1.48	1.25	6.80	1.47	1.25	6.45	1.44	1.25	5.99
648	1.56	1.25	6.08	1.49	1.25	5.80	1.43	1.25	5.42
653	1.47	1.25	6.78	1.46	1.25	6.38	1.43	1.25	5.82
654	1.58	1.23	4.80	1.52	1.23	4.65	1.45	1.23	4.48
656			*			*			*
657			*			*			*
660			*			*			*

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST D			TEST E			TEST F		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
602			*			*			*
604									
607									
610									
611									
615									
617									
619									
620									
623			*			*			*
624	1.39	1.22	5.16	1.42	1.22	4.95		1.19	4.70
627	1.42	1.16	5.10	1.44	1.14	4.92		1.17	4.87
628	1.42	1.16	4.20	1.42	1.18	4.10		1.12	4.12
631	1.42	1.14	5.59	1.44	1.14	5.01		1.16	5.09
634			*			*			*
638			*			*			*
644	1.41	1.16	5.55	1.42	1.19	5.12		1.15	5.32
645	1.42	1.13	5.14	1.44	1.16	5.18		1.16	5.16
647	1.40	1.19	5.58	1.42	1.18	4.02		1.14	5.50
648	1.41	1.17	5.77	1.42	1.19	4.84		1.15	5.01
653	1.40	1.12	5.15	1.41	1.18	4.87		1.15	5.00
654	1.41	1.19	5.42	1.43	1.20	4.08		1.14	5.30
656			*			*			*
657			*			*			*
660			*			*			*

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST G			TEST H			TEST I		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
602			*	1.42	1.21	6.24			*
604				1.44	1.19	5.01			
607				1.46	1.23	7.50			
610				1.40	1.22	6.70			
611				1.44	1.22	6.15			
615				1.41	1.21	6.00			
617				1.42	1.21	5.49			
619				1.42	1.22	6.09			
620				1.42	1.21	5.76			
623			*	1.44	1.22	6.30			
624		1.18	4.96	1.40	1.18	4.74			*
627		1.13	4.62			*	1.42	1.23	5.88
628		1.12	4.00				1.41	1.21	4.89
631		1.14	4.65				1.46	1.24	7.23
634			*				1.50	1.24	6.75
638			*				1.41	1.24	5.88
644		1.16	4.95				1.40	1.23	5.73
645		1.14	4.92				1.41	1.24	6.09
647		1.14	4.91				1.40	1.23	5.85
648		1.14	4.78				1.41	1.23	6.03
653		1.14	4.51				1.41	1.22	6.00
654		1.14	5.20				1.49	1.22	6.06
656			*				1.49	1.23	6.00
657			*				1.49	1.23	6.50
660			*			*	1.42	1.25	6.15

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST J			TEST K			TEST L		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
602	1.42	1.22	6.00	1.41	1.22	5.91			*
604	1.41	1.18	5.01	1.41	1.17	4.71			
607	1.43	1.24	7.26	1.44	1.23	7.11			
610	1.40	1.23	5.64	1.40	1.22	5.76			
611	1.42	1.23	5.94	1.41	1.23	5.94			
615	1.41	1.22	5.85	1.40	1.22	5.85			
617	1.39	1.22	5.49	1.39	1.22	5.64			
619	1.40	1.23	5.85	1.40	1.22	5.85			
620	1.40	1.22	5.61	1.40	1.22	5.70			
623	1.42	1.23	6.06	1.42	1.23	6.00			
624	1.40	1.20	4.20	1.40	1.19	4.05			*
627	1.43	1.23	5.85	1.42	1.23	6.00	1.45	1.23	5.85
628	1.43	1.21	4.83	1.41	1.21	5.00	1.45	1.21	4.95
631	1.47	1.24	7.03	1.46	1.24	7.25	1.49	1.25	6.90
634	1.44	1.24	6.75	1.45	1.23	7.20			*
638	1.42	1.24	5.94	1.41	1.24	6.25	1.45	1.24	6.15
644	1.41	1.23	5.79	1.40	1.23	6.05	1.43	1.24	5.90
645	1.42	1.23	6.09	1.41	1.24	6.30	1.45	1.24	6.25
647	1.42	1.23	5.88	1.41	1.24	6.15	1.45	1.24	6.00
648	1.42	1.24	6.03	1.42	1.24	6.25	1.44	1.24	6.10
653	1.44	1.22	6.00	1.42	1.22	6.20	1.47	1.23	6.00
654	1.46	1.22	6.03	1.44	1.23	6.30	1.47	1.23	5.90
656	1.50	1.23	5.80	1.45	1.22	6.15			*
657	1.50	1.23	6.50	1.45	1.23	6.85			*
660	1.42	1.24	6.10	1.45	1.24	6.60			*

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST A			TEST B			TEST C		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
661			*			*			*
719									
765									
770									
778									
779									
780									
783									
798									
801									
804									
810									
812									
813									
814									
815									
816									
818									
820									
822									
825									
826									
827									
829									
830			*			*			*

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST D			TEST E			TEST F		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
661									
719	1.38	1.20	4.05	1.40	1.21	4.20		1.18	4.29
765	1.39	1.23	5.35	1.41	1.23	4.98		1.20	5.32
770	1.40	1.23	5.55	1.42	1.23	5.10		1.20	5.28
778	1.39	1.21	4.50	1.40	1.21	4.08		1.18	4.20
779	1.39	1.20	5.06	1.40	1.20	4.00		1.16	4.20
780	1.38	1.21	4.35	1.40	1.21	4.02		1.18	4.26
783	1.41	1.22	5.77	1.43	1.23	5.36		1.20	5.35
798	1.41	1.24	5.80	1.44	1.24	5.50		1.21	5.51
801	1.41	1.23	5.81	1.44	1.24	5.40		1.20	5.41
804			*			*			*
810			|			|			|
812			|			|			|
813			|			|			|
814			|			|			|
815			|			|			|
816			|			|			|
818			|			|			|
820			|			|			|
822			|			|			|
825			|			|			|
826			|			|			|
827			|			|			|
829			|			|			|
830			*			*			*

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST G			TEST H			TEST I		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
661			*			*	1.45	1.24	7.50
719		1.17	4.10	1.39	1.18	4.80			*
765		1.19	5.40	1.40	1.21	5.34			
770		1.19	5.02	1.40	1.22	6.15			
778		1.17	4.03	1.39	1.18	4.59			
779		1.16	3.95	1.40	1.18	4.50			
780		1.17	4.20	1.39	1.19	4.83			
783		1.19	5.52	1.40	1.20	5.40			
798		1.20	5.47	1.41	1.22	5.79			
801		1.20	5.46	1.42	1.22	5.55			
804			*	1.45	1.25	6.45			
810				1.45	1.25	6.24			
812				1.45	1.25	6.30			
813				1.46	1.25	6.84			
814				1.45	1.25	6.90			*
815						*	1.44	1.24	6.87
816							1.43	1.23	6.45
818							1.42	1.23	6.18
820							1.42	1.24	6.30
822							1.42	1.23	6.33
825							1.42	1.23	6.21
826							1.42	1.23	6.18
827							1.42	1.23	6.15
829							1.43	1.23	6.60
830			*			*	1.44	1.23	6.36

* Test not performed

TABLE 6 (Cont'd) - CAPACITY TEST RESULTS
GULTON CELLS

Cell No.	TEST J			TEST K			TEST L		
	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours	End of Charge Volts	Volts After 1 hr. Discharge	Capacity Ampere-Hours
661	1.42	1.24	7.10	1.45	1.24	7.30			*
719	1.39	1.20	3.93	1.39	1.17	3.78			
765	1.39	1.22	4.44	1.39	1.20	4.20			
770	1.40	1.22	4.98	1.40	1.20	4.50			
778	1.39	1.22	3.90	1.39	1.16	3.75			
779	1.40	1.19	3.75	1.39	1.12	3.63			
780	1.39	1.20	3.78	1.39	1.14	3.69			
783	1.41	1.22	4.65	1.41	1.20	4.44			
798	1.41	1.23	5.04	1.41	1.22	4.74			
801	1.42	1.22	4.83	1.42	1.21	4.68			
804	1.44	1.24	5.76	1.43	1.24	6.00			
810	1.43	1.24	5.49	1.42	1.24	5.85			
812	1.42	1.24	5.25	1.41	1.24	5.76			
813	1.44	1.24	6.24	1.43	1.24	6.51			
814	1.43	1.24	6.39	1.43	1.24	6.51			
815	1.42	1.24	6.24	1.42	1.24	5.94			
816	1.42	1.23	5.55	1.41	1.23	5.16			
818	1.41	1.23	5.49	1.40	1.23	5.04			
820	1.41	1.23	5.49	1.40	1.23	4.98			
822	1.42	1.23	5.67	1.41	1.23	5.34			
825	1.41	1.23	5.49	1.40	1.23	5.10			
826	1.41	1.23	5.22	1.40	1.23	4.83			
827	1.41	1.23	5.34	1.40	1.23	4.89			
829	1.42	1.24	5.88	1.41	1.24	5.52			
830	1.42	1.24	5.67	1.42	1.24	5.49			*

* Test not performed

TABLE 7 - ELECTRICAL LEAKAGE TEST RESULTS
SONOTONE CELLS

Cell No.	Leakage Condition *		
	1	2	3
51	X		
52	X		
53	X		
54	X		
55	X		
56	X		
57	X		
58	X		
59	X		
60	X		
61	X		
62	X		
63	X		
64	X		
65	X		
66	X		
67	X		
68	X		
69	X		
70	X		
71	X		
72	X		
73	X		
74	X		
75	X		

Cell No.	Leakage Condition *		
	1	2	3
R34	X		
R35	X		
R36	X		
R37	X		
R38	X		
R39	X		
R40	X		
R41	X		
R42	X		
R43	X		
R44			X
R45	X		
R46	X		
R47	X		
R48	X		
R49	X		
R50	X		
R51	X		
R52		X	
R53	X		
R54	X		
R55	X		
R56	X		
R57	X		
R58			X

Note: * Condition 1 - Terminal voltage above 1.0 volts after 24 hour stand.
Condition 2 - Terminal voltage above 1.2 volts after 5 minute C/5 amp charge and 24 hour stand.
Condition 3 - Terminal voltage below 1.2 volts after Condition 2.

TABLE 8 - ELECTRICAL LEAKAGE TEST RESULTS
GOULD-NATIONAL CELLS

Cell No.	Leakage Condition *		
	1	2	3
1	X		
2	X		
3			
4		X	
5	X		
6	X		
7	X		
8	X		
9	X		
10	X		
11	X		
12	X		
13			X
14	X		
15	X		
16	X		
17		X	
18	X		
19	X		
20	X		
21	X		
22	X		
23	X		
24	X		
25		X	

Cell No.	Leakage Condition *		
	1	2	3
26	X		
27	X		
28	X		
29	X		
30	X		
31	X		
32	X		
33	X		
34			
35	X		
36	X		
37	X		
38	X		
39	X		
40			X
41	X		
42	X		
43	X		
44	X		
45	X		
46	X		
47	X		
48	X		
49	X		
50	X		

Note: * Condition 1 - Terminal voltage above 1.0 volts after 24 hour stand.
Condition 2 - Terminal voltage above 1.2 volts after 5 minute C/5 amp charge & 24 hour stand.
Condition 3 - Terminal voltage below 1.2 volts after Condition 2.

TABLE 9 - ELECTRICAL LEAKAGE TEST RESULTS
GULTON CELLS

Cell No.	Leakage Condition*		
	1	2	3
602		X	
604		X	
607		X	
610		X	
611	X		
615	X		
617		X	
619		X	
620		X	
623		X	
624	X		
627	X		
628	X		
631	X		
634			X
638		X	
644	X		
645	X		
647	X		
648	X		
653	X		
654	X		
656		X	
657		X	
660		X	

Cell No.	Leakage Condition*		
	1	2	3
661		X	
719	X		
765	X		
770			X
778	X		
779	X		
780	X		
783	X		
798	X		
801	X		
804	X		
810	X		
812	X		
813	X		
814	X		
815	X		
816	X		
818	X		
820	X		
822	X		
825	X		
826	X		
827	X		
829	X		
830	X		

Note: Condition 1 - Terminal voltage above 1.0 volts after 24 hour stand
Condition 2 - Terminal voltage above 1.2 volts after 5 minute C/5 amp charge & 24 hour stand
Condition 3 - Terminal voltage below 1.2 volts after Condition 2

TABLE 10 - OVERCHARGE TEST RESULTS
SONOTONE CELLS

Cell No.	Overcharge (steady volts)		
	C/5	C/10	C/20
51	1.40	1.39	1.39
52	1.43	1.40	1.40
53	1.41	1.39	1.39
54	1.41	1.39	1.39
55	1.40	1.38	1.38
56	1.40	1.39	1.39
57	1.42	1.40	1.40
58	1.41	1.39	1.39
59	1.41	1.39	1.39
60	I.41	1.39	1.39
61	1.41	1.39	1.39
62	1.39	1.38	1.38
63	I.41	1.38	1.38
64	1.39	1.38	1.38
65	1.41	1.39	1.39
66	1.41	1.39	1.39
67	I.40	1.39	1.39
68	1.40	1.39	1.39
69	1.40	1.38	1.39
70	1.43	I.40	1.40
71	1.42	1.38	1.38
72	1.41	1.38	1.39
73	1.41	1.39	1.39
74	1.41	1.39	1.39
75	1.42	1.38	1.38

Cell No.	Overcharge (steady volts)		
	C/5	C/10	C/20
R34	1.40	1.39	1.39
R35	1.40	1.39	1.39
R36	1.40	1.39	1.39
R37	1.39	1.38	1.38
R38	1.40	1.38	1.38
R39	1.41	1.39	1.39
R40	1.40	1.39	1.39
R41	1.40	1.39	1.39
R42	1.41	1.39	1.39
R43	1.40	1.39	1.39
R44			
R45	1.40	1.39	1.39
R46	1.41	1.39	1.39
R47	1.41	1.40	1.40
R48	1.41	1.40	1.40
R49	1.40	1.39	1.39
R50	1.41	1.39	1.39
R51	1.41	1.39	1.39
R52	1.41	1.38	1.38
R53	1.41	1.39	1.39
R54	1.42	1.40	1.40
R55	1.41	1.39	1.39
R56	1.41	1.39	1.39
R57	1.42	1.39	1.39
R58			

TABLE 11 - OVERCHARGE TEST RESULTS
GOULD-NATIONAL CELLS

Cell No.	Overcharge (steady volts)		
	C/5	C/10	C/20
1	1.47	1.46	1.45
2	1.46	1.45	1.43
3			
4	1.45	1.45	1.44
5	1.45	1.44	1.44
6	1.45	1.44	1.44
7	1.46	1.45	1.44
8	1.44	1.43	1.42
9	1.46	1.46	1.44
10	1.47	1.47	1.46
11	1.44	1.43	1.43
12	1.46	1.45	1.44
13			
14	1.46	1.45	1.45
15	1.44	1.44	1.43
16	1.44	1.44	1.43
17	1.45	1.44	1.43
18	1.46	1.46	1.44
19	1.46	1.46	1.45
20	1.46	1.45	1.44
21	1.46	1.45	1.44
22	1.45	1.45	1.44
23	1.46	1.46	1.44
24	1.45	1.44	1.44
25	1.44	1.43	1.43

Cell No.	Overcharge (steady volts)		
	C/5	C/10	C/20
26	1.44	1.44	1.43
27	1.46	1.46	1.45
28	1.46	1.45	1.44
29	1.44	1.44	1.43
30	1.44	1.44	1.43
31	1.45	1.45	1.44
32	1.46	1.45	1.44
33	1.45	1.45	1.44
34	1.44	1.44	1.43
35	1.46	1.45	1.45
36	1.45	1.44	1.43
37	1.44	1.44	1.43
38	1.45	1.44	1.44
39	1.44	1.44	1.43
40			
41	1.45	1.44	1.44
42	1.44	1.43	1.43
43	1.44	1.44	1.43
44	1.44	1.44	1.43
45	1.44	1.43	1.42
46	1.44	1.44	1.43
47	1.44	1.44	1.43
48	1.44	1.44	1.43
49	1.45	1.45	1.44
50	1.45	1.44	1.43

TABLE 12 - OVERCHARGE TEST RESULTS
GULTON CELLS

Cell No.	Overcharge (steady volts)		
	C/5	C/10	C/20
602	1.41	1.40	1.40
604	1.41	1.40	1.39
607	1.42	1.41	1.41
610	1.41	1.40	1.40
611	1.41	1.41	1.40
615	1.41	1.40	1.40
617	1.40	1.40	1.39
619	1.41	1.40	1.40
620	1.41	1.40	1.40
623	1.42	1.40	1.40
624	1.40	1.39	1.39
627	1.42	1.40	1.40
628	1.41	1.40	1.40
631	1.43	1.42	1.41
634	1.42	1.42	1.41
638	1.41	1.41	1.40
644	1.40	1.40	1.39
645	1.41	1.41	1.40
647	1.41	1.40	1.40
648	1.42	1.41	1.40
653	1.42	1.41	1.40
654	1.42	1.41	1.40
656	1.42	1.41	1.41
657	1.42	1.41	1.41
660	1.43	1.41	1.41

Cell No.	Overcharge (steady volts)		
	C/5	C/10	C/20
661	1.43	1.42	1.41
719	1.40	1.39	1.39
765	1.40	1.40	1.39
770	1.41	1.40	1.40
778	1.40	1.40	1.39
779	1.41	1.40	1.40
780	1.40	1.39	1.39
783	1.41	1.40	1.40
798	1.41	1.40	1.40
801	1.42	1.40	1.40
804	1.42	1.40	1.40
810	1.42	1.41	1.40
812	1.41	1.40	1.39
813	1.42	1.42	1.41
814	1.42	1.42	1.41
815	1.41	1.40	1.40
816	1.40	1.39	1.39
818	1.42	1.41	1.40
820	1.41	1.40	1.40
822	1.41	1.40	1.40
825	1.40	1.39	1.39
826	1.42	1.40	1.40
827	1.41	1.40	1.40
829	1.42	1.41	1.40
830	1.42	1.41	1.40

TABLE 13 - INTERNAL RESISTANCE TEST RESULTS
SONOTONE CELLS

Cell No.	Internal Resistance (Milliohms)	Cell No.	Internal Resistance (Milliohms)
51	35	R34	38
52	56	R35	35
53	48	R36	36
54	48	R37	40
55	45	R38	39
56	42	R39	42
57	62	R40	35
58	52	R41	42
59	47	R42	45
60	44	R43	62
61	43	R44	
62	36	R45	60
63	45	R46	37
64	39	R47	40
65	115	R48	39
66	40	R49	36
67	44	R50	60
68	39	R51	40
69	36	R52	36
70	84	R53	39
71	45	R54	48
72	51	R55	36
73	45	R56	47
74	66	R57	72
75	45	R58	

TABLE 14 - INTERNAL RESISTANCE TEST RESULTS
GOULD-NATIONAL CELLS

Cell No.	Internal Resistance (Milliohms)	Cell No.	Internal Resistance (Milliohms)
1	18	26	6
2	9	27	5
3		28	5
4	9	29	6
5	9	30	10
6	9	31	8
7	15	32	8
8	18	33	8
9	9	34	6
10	9	35	9
11	9	36	6
12	12	37	6
13		38	9
14	9	39	6
15	6	40	
16	6	41	10
17	6	42	9
18	5	43	9
19	5	44	8
20	6	45	10
21	12	46	9
22	6	47	9
23	6	48	9
24	6	49	6
25	6	50	12

TABLE 15 - INTERNAL RESISTANCE TEST RESULTS
GULTON CELLS

Cell No.	Internal Resistance (Milliohms)	Cell No.	Internal Resistance (Milliohms)
602	23.0	661	21.0
604	23.0	719	25.0
607	25.0	765	23.0
610	23.0	770	25.0
611	49.0	778	22.0
615	25.0	779	24.0
617	23.0	780	27.0
619	25.0	783	22.0
620	28.0	798	28.0
623	35.0	801	23.0
624	23.0	804	21.0
627	30.0	810	23.0
628	27.0	812	18.0
634	20.0	813	21.0
632	24.0	814	19.0
638	22.0	815	44.0
644	26.0	816	25.0
645	23.0	818	19.0
647	19.0	820	28.0
648	21.0	822	22.0
653	25.0	825	23.0
654	28.0	826	21.0
656	23.0	827	26.0
657	27.0	829	24.0
660	28.0	830	20.0

TABLE 16 - SUMMARY OF FAILURE ANALYSIS RESULTS
SONOTONE CELLS

CELL NUMBER	56	57	58	59
TEST CONDITION	40% Discharge at 25°C	40% Discharge at 25°C	40% Discharge at 25°C	40% Discharge at 25°C
CHARGE CURRENT	1.75 Amps.	1.75 Amps.	1.75 Amps.	1.75 Amps.
DISCHARGE CURRENT	2.10 Amps.	2.10 Amps.	2.10 Amps.	2.10 Amps.
VOLTAGE LIMIT	1.50 volts/cell	1.50 volts/cell	1.50 volts/cell	1.50 volts/cell
CYCLES COMPLETED	537	6146	6146	6146
EXTERNAL DAMAGE				
A. CASE DAMAGE	None	None	None	None
B. CASE DISTORTION	Minor	None	None	None
C. SEAL LEAKAGE	Minor	None	None	None
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	1.42 AH to 1.0 volts	1.05 AH to 1.0 volts 1.15 AH to 0.6 volts	1.20 AH to 1.0 volts 1.35 AH to 0.6 volts	1.40 AH to 1.0 volts 1.59 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.36V. after 5 mins. 1.25V. after 32 Hrs. 0.04V. after 96 Hrs.	1.29V. after 1.0 Hrs. 1.26V. after 24 Hrs. 1.22V. after 120 Hrs.	1.29V. after 1.0 Hrs. 1.27V. after 24 Hrs. 1.21V. after 120 Hrs.	1.28V. after 1.0 Hrs. 1.24V. after 24 Hrs. 1.21V. after 120 Hrs.

TABLE 16 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
SONOTONE CELLS

CELL NUMBER	63	67	69	70
TEST CONDITION	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C
CHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	0.525 Amps.
DISCHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	0.525 Amps.
VOLTAGE LIMIT	None	None	None	None
CYCLES COMPLETED	3288	6195	4008	5545
EXTERNAL DAMAGE				
A. CASE DAMAGE	None	None	None	None
B. CASE DISTORTION	None	Minor	None	Minor
C. SEAL LEAKAGE	None	Minor	None	None
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	Would Not Accept Charge	Would Not Accept Charge	0.875 AH to 1.0 volts 1.800 AH to 0.6 volts	0.02 AH to 1.0 volts 0.02 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	Would Not Accept Charge	Would Not Accept Charge	1.33V.. after 1.0 Hrs. 1.24V. after 48 Hrs. 0.00V. after 108 Hrs.	1.31V. after 0.5 Hrs. 1.25V. after 8.0 Hrs. 0.89V. after 72 Hrs. 0.04V. after 120 Hrs.

TABLE 16 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
SONOTONE CELLS

CELL NUMBER	71	75	R45	R46
TEST CONDITION	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C
CHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	0.525 Amps.
DISCHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	0.525 Amps.
VOLTAGE LIMIT	None	None	None	None
CYCLES COMPLETED	5031	4234	7157	5100
EXTERNAL DAMAGE				
A. CASE DAMAGE	None	None	None	None
B. CASE DISTORTION	None	None	None	Minor
C. SEAL LEAKAGE	None	None	None	None
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	1.38 AH to 1.0 volts 1.88 AH to 0.6 volts	Would Not Accept Charge	1.87 AH to 1.0 volts 2.10 AH to 0.6 volts	
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.31V. after 10 Mins. 1.25V. after 8.0 Hrs. 0.91V. after 72 Hrs.	Would Not Accept Charge	1.36V. after 1.0 Hrs. 1.28V. after 24 Hrs. 1.22V. after 120 Hrs.	

TABLE 16 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
SONOTONE CELLS

CELL NUMBER	R47	R48	R56	
TEST CONDITION	10% Discharge at 50°C	10% Discharge at 50°C	25% Discharge at 25°C	
CHARGE CURRENT	0.525 Amps.	0.525 Amps.	1.09 Amps.	
DISCHARGE CURRENT	0.525 Amps.	0.525 Amps.	1.31 Amps.	
VOLTAGE LIMIT	None	None	1.50 volts/cell	
CYCLES COMPLETED	7157	7157	7811	
EXTERNAL DAMAGE				
A. CASE DAMAGE	None	None	None	
B. CASE DISTORTION	Minor	None	None	
C. SEAL LEAKAGE	None	None	None	
D. TERMINAL DAMAGE	None	None	None	
POST-FAILURE CAPACITY	Would Not Accept Charge	Would Not Accept Charge		
POST-FAILURE OPEN-CIRCUIT VOLTAGE	Would Not Accept Charge	Would Not Accept Charge		

TABLE 17 - SUMMARY OF FAILURE ANALYSIS RESULTS
GOULD-NATIONAL CELLS

CELL NUMBER	5	7	10	20
TEST CONDITION	25% Discharge at 25°C	25% Discharge at 25°C	25% Discharge at 25°C	10% Discharge at 50°C
CHARGE CURRENT	1.09 Amps.	1.09 Amps.	1.09 Amps.	0.525 Amps.
DISCHARGE CURRENT	1.31 Amps.	1.31 Amps.	1.31 Amps.	0.525 Amps.
VOLTAGE LIMIT	1.52 volts/cell	1.52 volts/cell	1.52 volts/cell	None
CYCLES COMPLETED	5110	2487	4608	2973
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	Minor	None	None
B. CASE DISTORTION	None	Extensive	None	None
C. SEAL LEAKAGE	Extensive	Minor	Extensive	Minor
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY		0.5 AH to 1.0 volts 1.96 AH to 0.6 volts	0.82 AH to 1.0 volts 2.54 AH to 0.6 volts	0.22 AH to 1.0 volts 0.34 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE		1.41V. after 0.5 Hrs. 1.36V. after 8.0 Hrs. 0.04V. after 72 Hrs. 0.02V. after 120 Hrs.	1.33V. after 1.0 Hrs. 1.29V. after 24 Hrs. 1.27V. after 120 Hrs.	1.25V. after 25 Hrs.

TABLE I7 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
GOULD-NATIONAL CELLS

CELL NUMBER	21	23	28	31
TEST CONDITION	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C
CHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	0.525 Amps.
DISCHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	0.525 Amps.
VOLTAGE LIMIT	None	None	None	None
CYCLES COMPLETED	2668	5536	7101	7849
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	None	None	None
B. CASE DISTORTION	None	Minor	Minor	None
C. SEAL LEAKAGE	Extensive	Extensive	Minor	Minor
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	0.03 AH to 1.0 Volts 0.44 AH to 0.6 Volts	0.2 AH to 1.0 Volts 0.2 AH to 0.6 Volts	0.93 AH to 1.0 Volts 0.96 AH to 0.6 Volts	0.94 AH to 1.0 Volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.26V. after 8 Hrs. 1.24V. after 48 Hrs.	1.27V. after 0.5 Hrs. 1.24V. after 8 Hrs. 1.12V. after 72 Hrs. 0.85V. after 120 Hrs.	1.34V. after 1.0 Hrs. 1.29V. after 24 Hrs. 0.00V. after 120 Hrs.	

TABLE 17 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
GOULD-NATIONAL CELLS

CELL NUMBER	32	33	36	37
TEST CONDITION	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C	25% Discharge at 25°C
CHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	1.09 Amps.
DISCHARGE CURRENT	0.525 Amps.	0.525 Amps.	0.525 Amps.	1.31 Amps.
VOLTAGE LIMIT	None	None	None	1.52 volts/cell
CYCLES COMPLETED	7348	7849	3372	2487
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	None	None	None
B. CASE DISTORTION	None	None	None	None
C. SEAL LEAKAGE	Minor	Minor	Minor	Extensive
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	None	0.15 AH to 1.0 volts	0.03 AH to 1.0 volts 0.41 AH to 0.6 volts	0.13 AH to 1.0 volts 2.10 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.22V. after 1.0 Hrs. 0.54V. after 24 Hrs. 0.00V. after 28 Hrs.		1.19V. after 25 Hrs. 1.17V. after 48 Hrs. 1.10V. after 110 Hrs.	1.40V. after 0.5 Hrs. 1.36V. after 8.0 Hrs. 1.29V. after 72 Hrs. 1.28V. after 120 Hrs.

TABLE 17 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
GOULD-NATIONAL CELLS

CELL NUMBER	39	41	42	43
TEST CONDITION	25% Discharge at 25°C	10% Discharge at 50°C	10% Discharge at 50°C	40% Discharge at 25°C
CHARGE CURRENT	1.09 Amps.	0.525 Amps.	0.525 Amps.	1.75 Amps.
DISCHARGE CURRENT	1.31 Amps.	0.525 Amps.	0.525 Amps.	2.10 Amps.
VOLTAGE LIMIT	1.52 volts/cell	None	None	1.54 volts/cell
CYCLES COMPLETED	5110	3216	3576	1282
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	None	None	None
B. CASE DISTORTION	None	None	None	None
C. SEAL LEAKAGE	Extensive	Minor	Minor	Extensive
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY		0.38 AH to 1.0 volts 0.80 AH to 0.6 volts	0.03 AH to 0.6 voltss	0.44 AH to 1.0 volts 0.92 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE		1.26V. after 25 Hrs. 1.24V. after 48 Hrs. 1.17V. after 110 Hrs.	1.19V. after 1.0 Hrs. 1.10V. after 24 Hrs. 0.82V. after 48 Hrs. 0.08V. after 120 Hrs.	1.38V. after 0.5 Hrs. 1.34V. after 16 Hrs. 1.34V. after 20 Hrs.

TABLE 17 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
GOULD-NATIONAL CELLS

CELL NUMBER	45	46	49	50
TEST CONDITION	40% Discharge at 25°C	40% Discharge at 25°C	40% Discharge at 25°C	40% Discharge at 25°C
CHARGE CURRENT	1.75 Amps.	1.75 Amps.	1.75 Amps.	1.75 Amps.
DISCHARGE CURRENT	2.10 Amps.	2.10 Amps.	2.10 Amps.	2.10 Amps.
VOLTAGE LIMIT	1.54 volts/cell	1.54 volts/cell	1.54 volts/cell	1.54 volts/cell
CYCLES COMPLETED	1282	864	1282	864
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	None	None	None
B. CASE DISTORTION	None	None	None	None
C. SEAL LEAKAGE	Extensive	Minor	Extensive	Minor
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	1.03 AH to 1.0 volts 1.73 AH to 0.6 volts	1.57 AH to 1.0 volts 2.42 AH to 0.6 volts	0.91 AH to 1.0 volts 2.14 AH to 0.6 volts	1.84 AH to 1.0 volts 2.51 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.40V. after 0.5 Hrs. 1.36V. after 16 Hrs. 1.36V. after 20 Hrs.	1.39V. after 1.0 Hrs. 1.34V. after 24 Hrs. 1.33V. after 120 Hrs.	1.38V. after 0.5 Hrs. 1.36V. after 16 Hrs. 1.35V. after 20 Hrs.	1.39V. after 1.0 Hrs. 1.35V. after 24 Hrs. 1.32V. after 48 Hrs.

TABLE 18 - SUMMARY OF FAILURE ANALYSIS RESULTS
GULTON CELLS

CELL NUMBER	610	611	624	638
TEST CONDITION	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 50°C	10% Discharge at 25°C
CHARGE CURRENT	0.90 Amps.	0.90 Amps.	0.90 Amps.	0.75 Amps.
DISCHARGE CURRENT	0.90 Amps.	0.90 Amps.	0.90 Amps.	0.90 Amps.
VOLTAGE LIMIT	None	None	None	1.50 volts/cell
CYCLES COMPLETED	5632	7531	8456	7098
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	None	None	None
B. CASE DISTORTION	None	Extensive	Minor	Extensive
C. SEAL LEAKAGE	None	None	None	None
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY	4.5 AH to 1.0 volts 5.1 AH to 0.6 volts	Would not Accept Charge	Would not Accept Charge	4.6 AH to 1.0 volts 4.8 AH to 0.6 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.38 V. after 0.5 Hrs. 1.29 V. after 8.0 Hrs. 0.07 V. after 72 Hrs. 0.01 V. after 120 Hrs.	Would Not Accept Charge	Would Not Accept Charge	1.33 V. after 4.0 Hrs. 1.26 V. after 24 Hrs. 0.81 V. after 56 Hrs. 0.00 V. after 120 Hrs.

TABLE 18 (Cont'd) - SUMMARY OF FAILURE ANALYSIS RESULTS
GULTON CELLS

CELL NUMBER	656	813	814	829
TEST CONDITION	25% Discharge at 25°C	25% Discharge at 25°C	25% Discharge at 25°C	10% Discharge at 25°C
CHARGE CURRENT	1.88 Amps.	1.88 Amps.	1.88 Amps.	0.75 Amps.
DISCHARGE CURRENT	2.25 Amps.	2.25 Amps.	2.25 Amps.	0.90 Amps.
VOLTAGE LIMIT	1.50 volts/cell	1.50 volts/cell	1.50 volts/cell	1.50 volts/cell
CYCLES COMPLETED	1298	1270	1416	2263
EXTERNAL DAMAGE				
A. CASE LEAKAGE	None	None	None	None
B. CASE DISTORTION	None	None	None	None
C. SEAL LEAKAGE	None	None	None	None
D. TERMINAL DAMAGE	None	None	None	None
POST-FAILURE CAPACITY		Would Not Accept Charge		1.0 AH to I.0 volts
POST-FAILURE OPEN-CIRCUIT VOLTAGE	1.34V. after 0.25 Hrs. 1.31V. after 2.00 Hrs. 0.06V. after 46.0 Hrs.	Would Not Accept Charge	1.38V. after 0.25 Hrs. 0.11V. after 16.0 Hrs.	1.35V. after 0.5 Hrs. 1.24V. after 24.0 Hrs. 0.03V. after 96.0 Hrs.

Figure 1 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at -10°C
Sonotone Cells

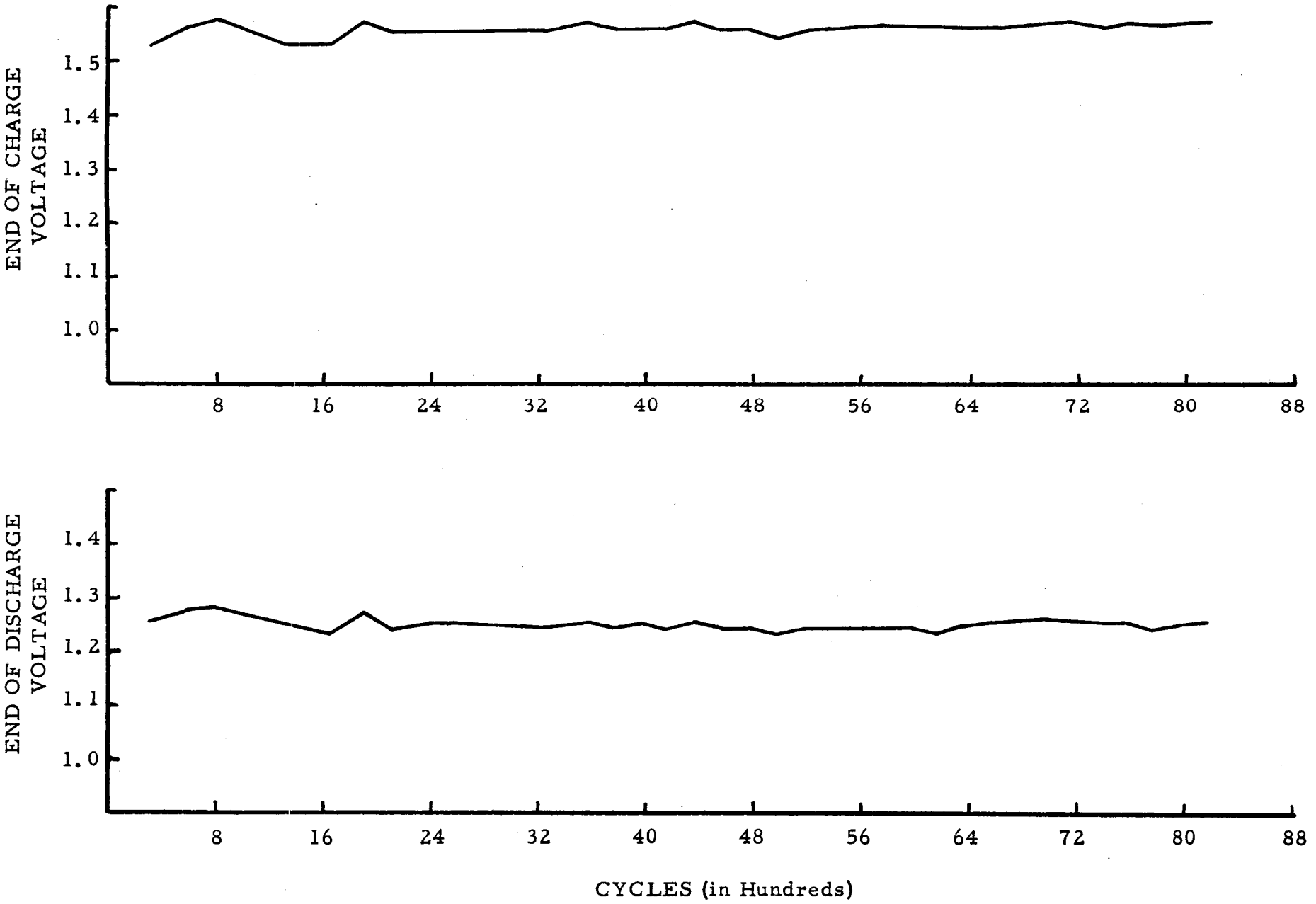


Figure 2 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 25°C
Sonotone Cells

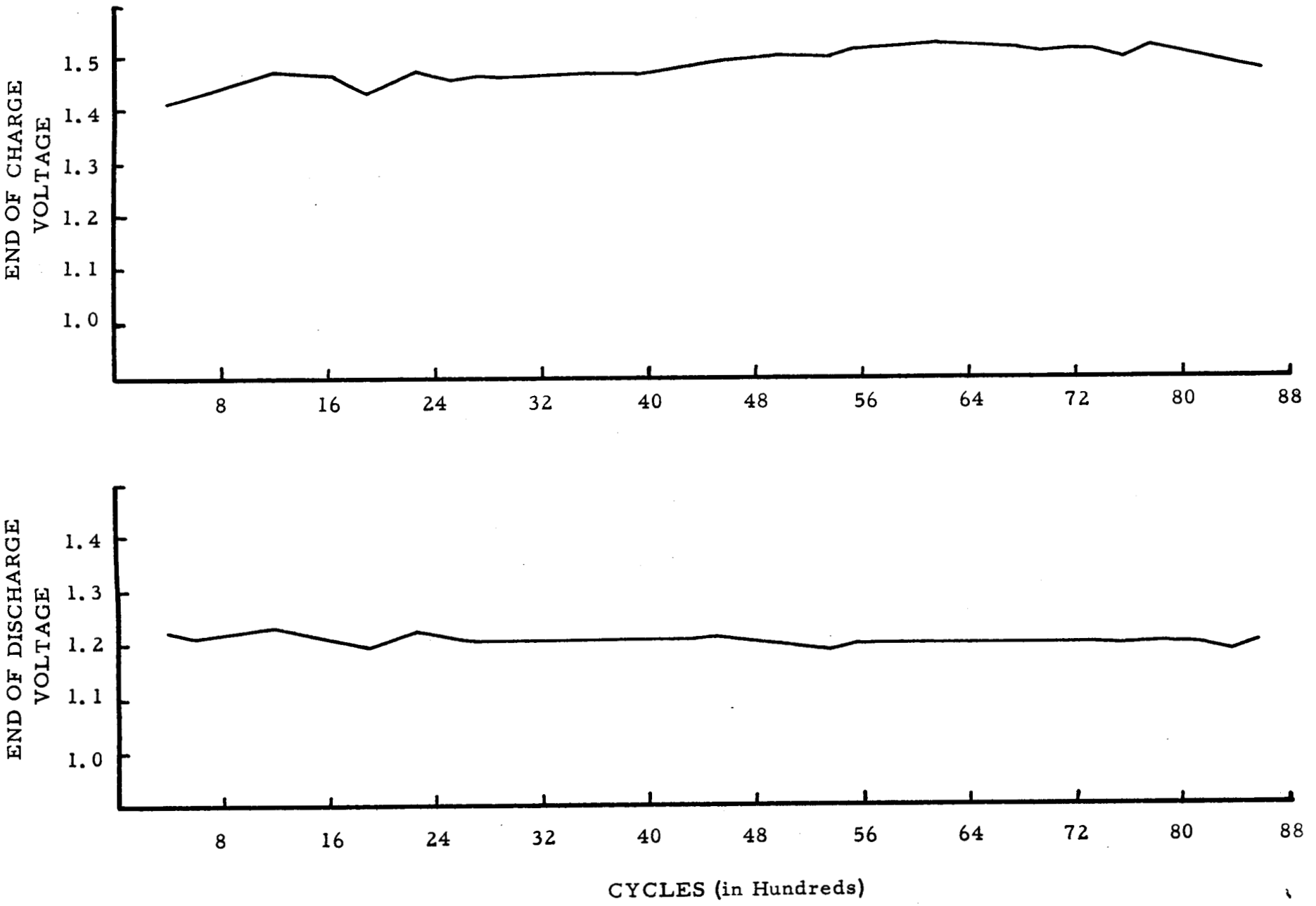


Figure 3 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 50°C
Sonotone Cells

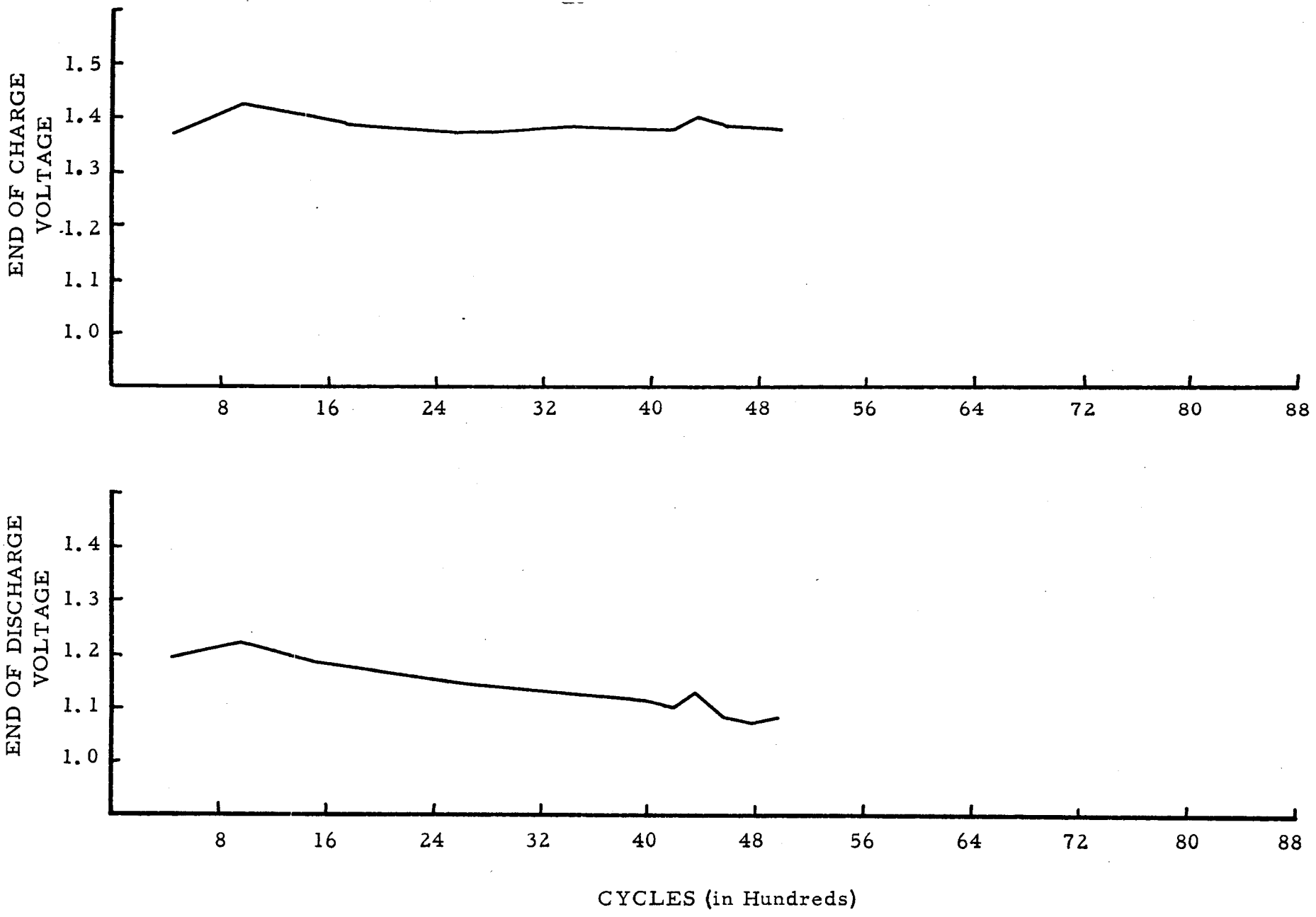


Figure 4 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 25% Discharge at 25°C
Sonotone Cells

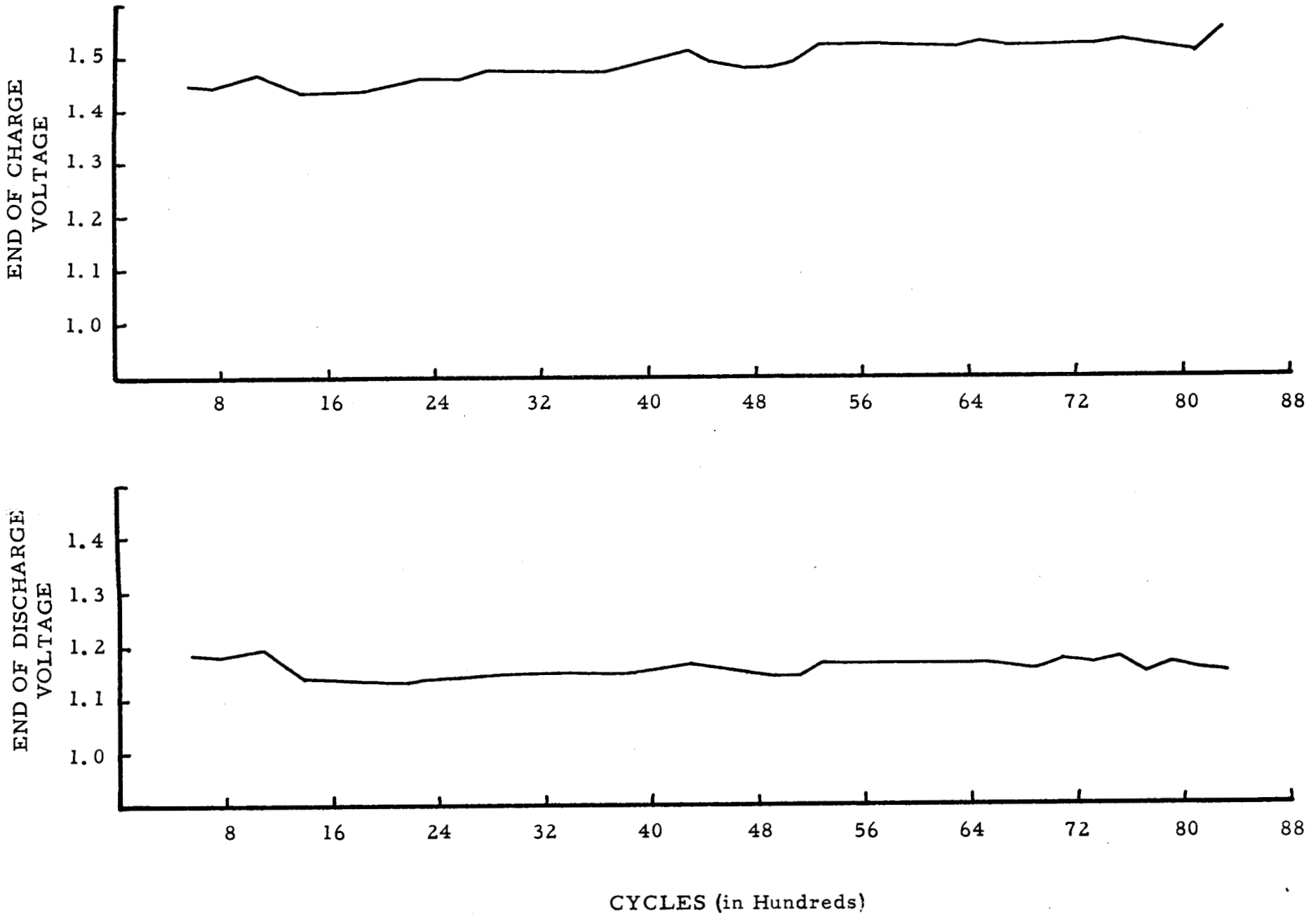


Figure 5 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 40% Discharge at 25°C
Sonotone Cells

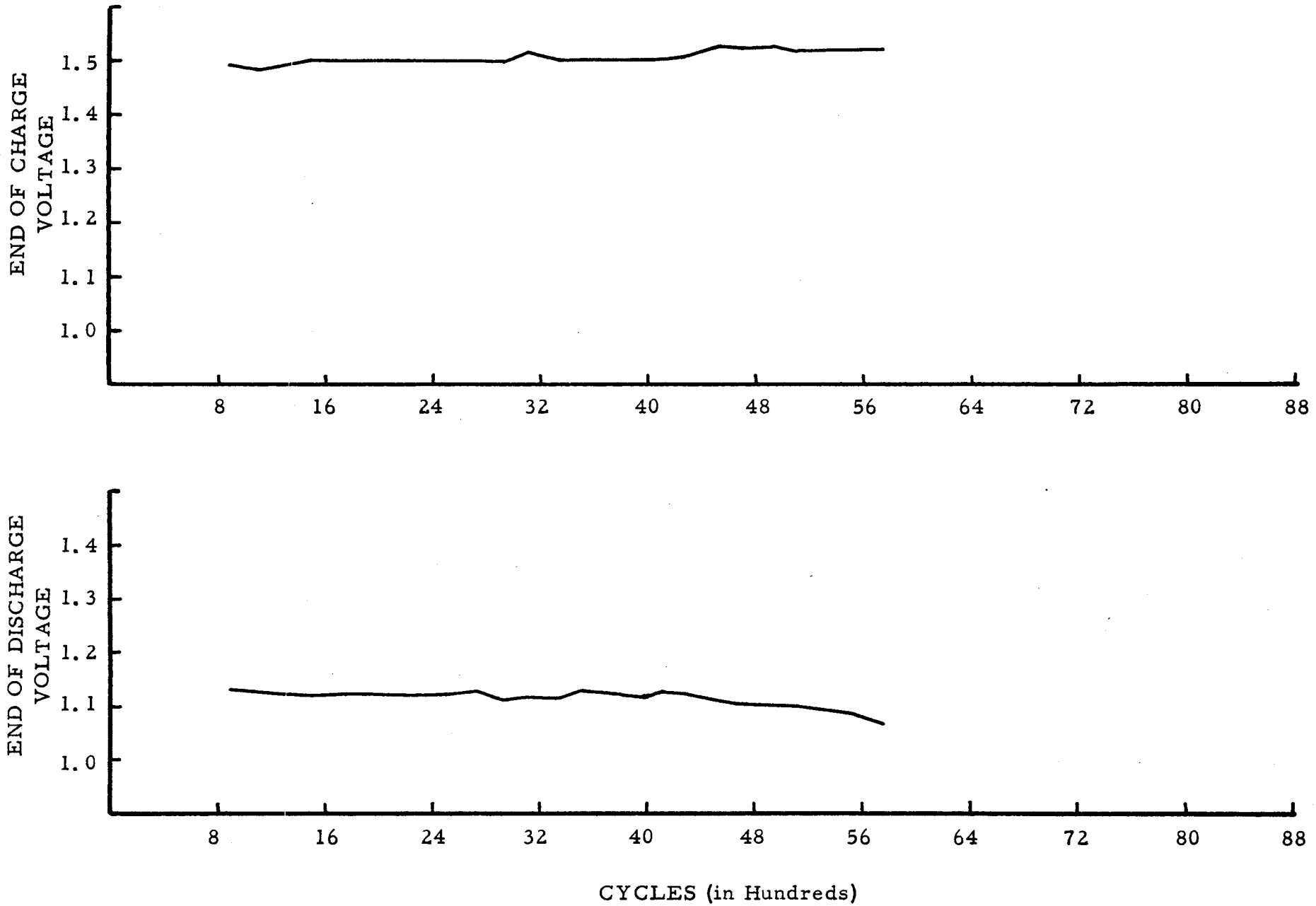


Figure 6 - Endpoint Voltage Characteristics - Cell #54
Cycle Life: 10% Discharge at -10°C
Sonotone Cell

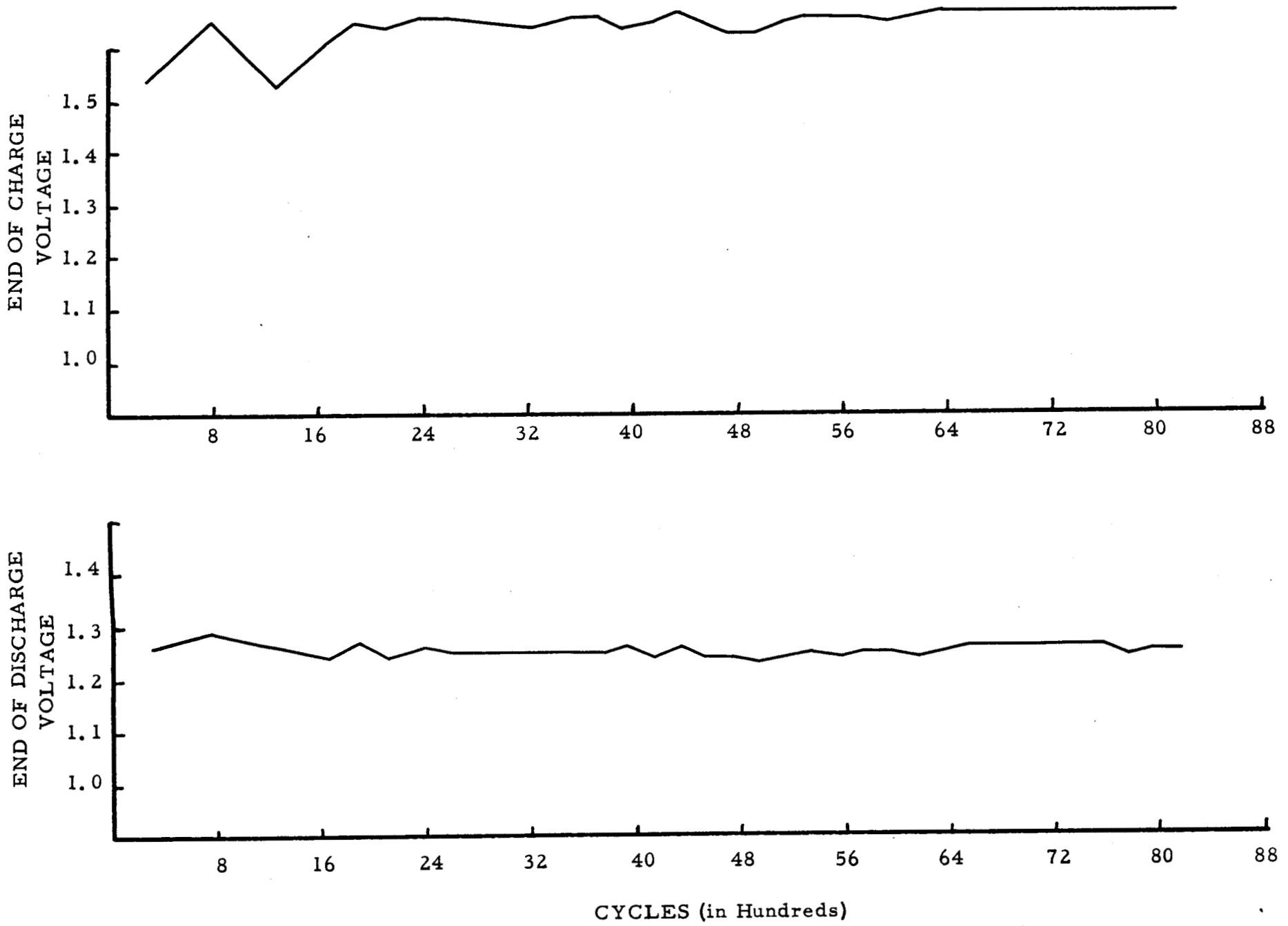


Figure 7 - Endpoint Voltage Characteristics - Cell #R38
Cycle Life: 10% Discharge at -10°C
Sonotone Cell

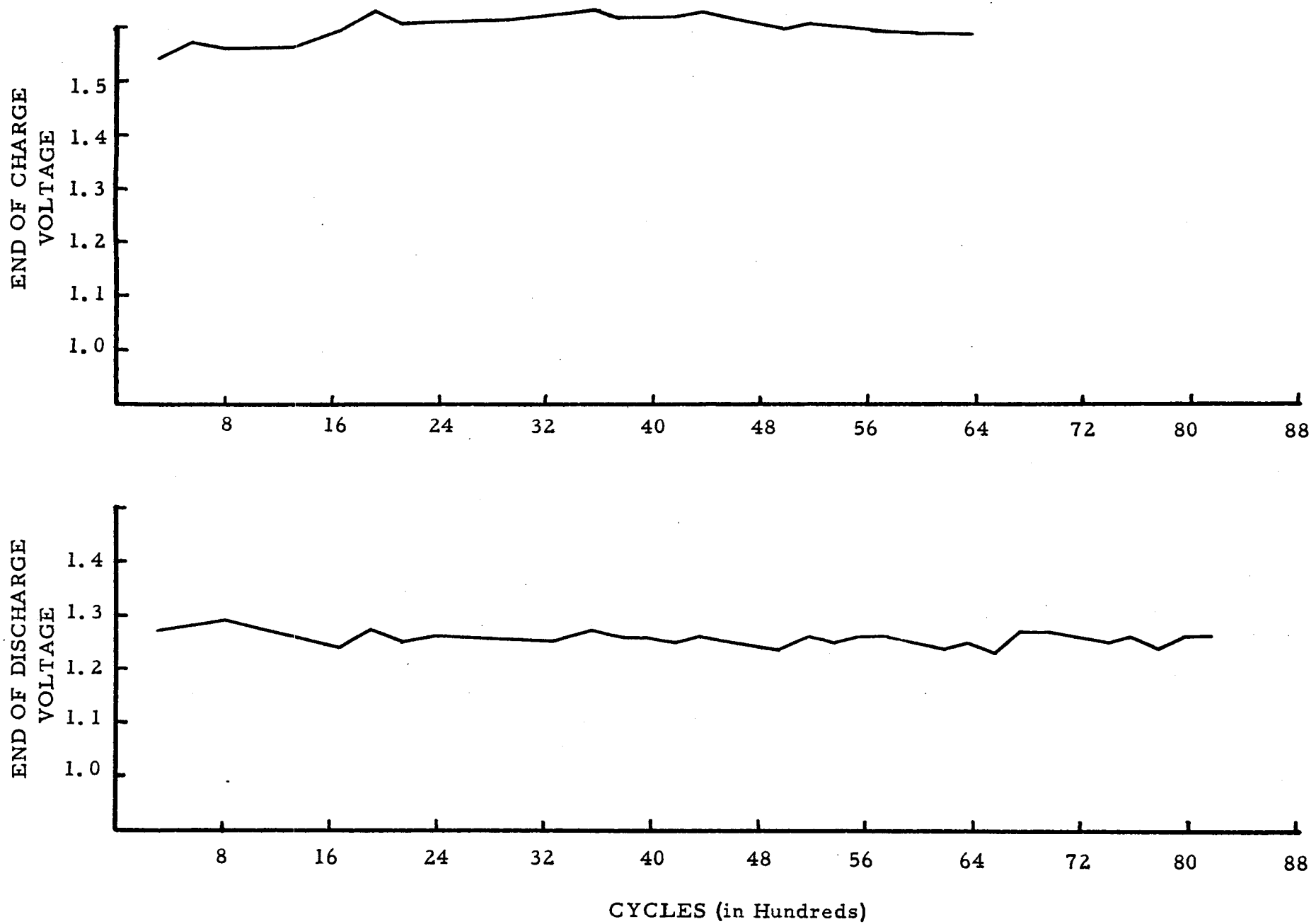


Figure 8 - Endpoint Voltage Characteristics - Cell #74
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

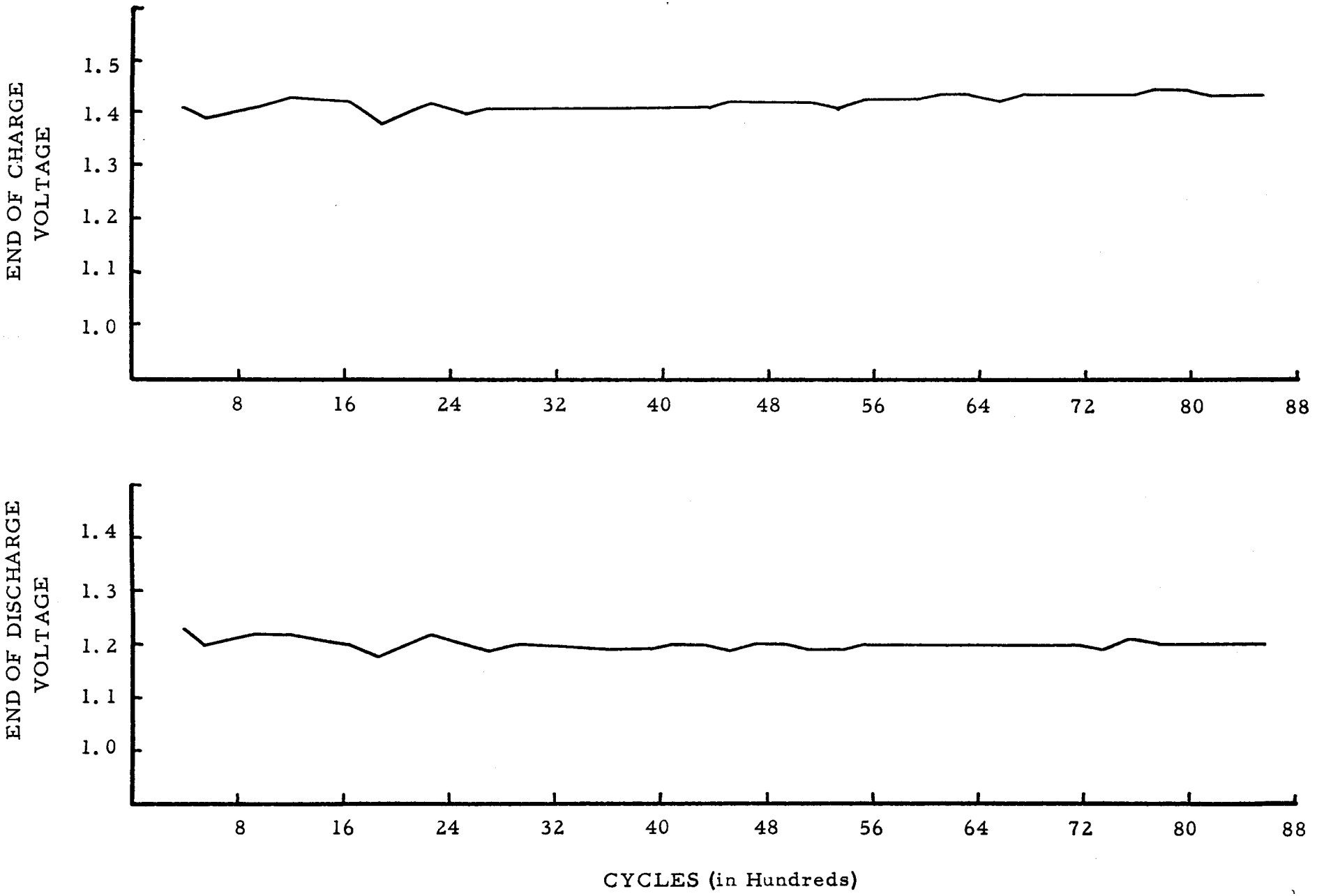


Figure 9 - Endpoint Voltage Characteristics - Cell #R39
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

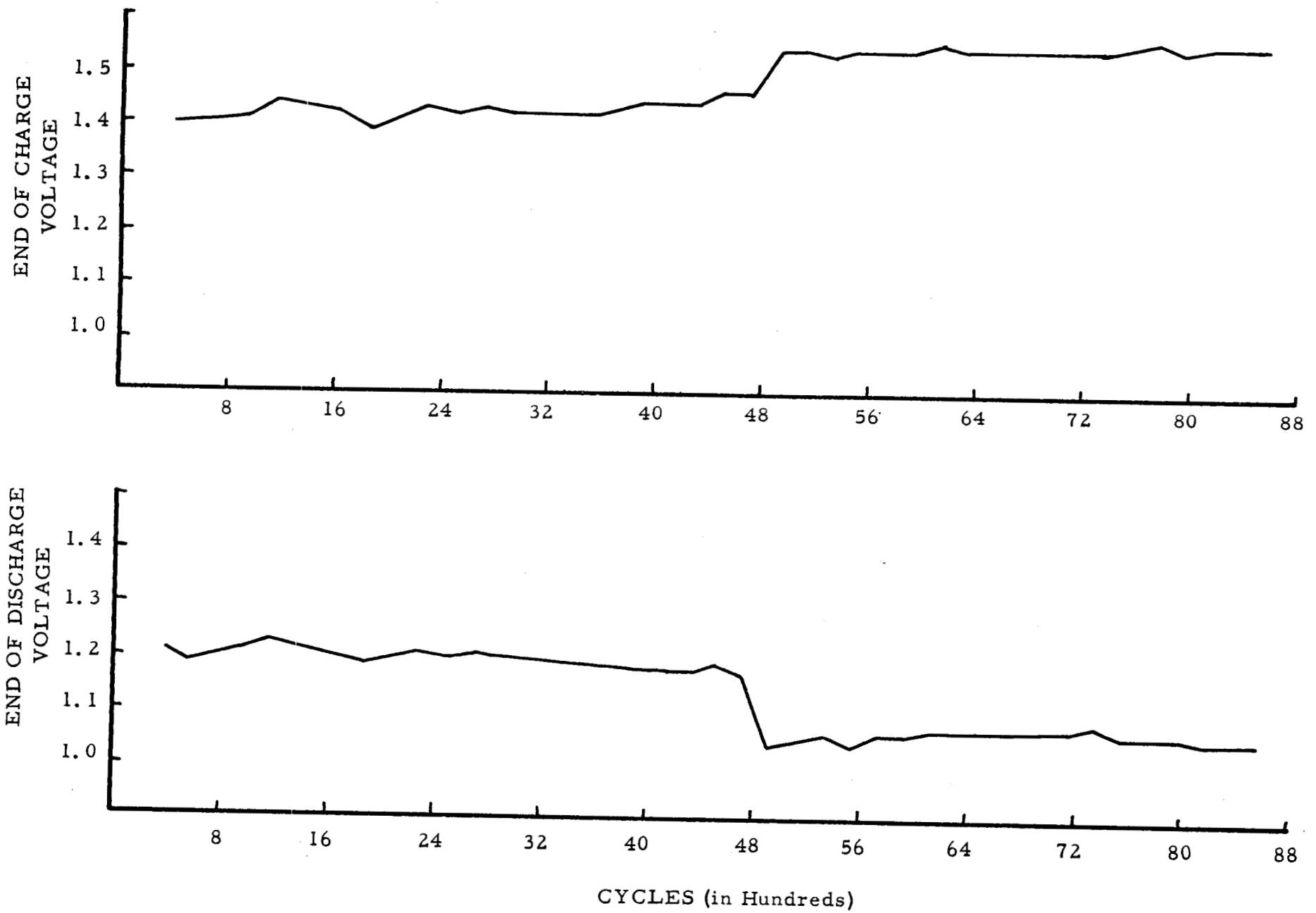


Figure 10 - Endpoint Voltage Characteristics - Cell #75
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

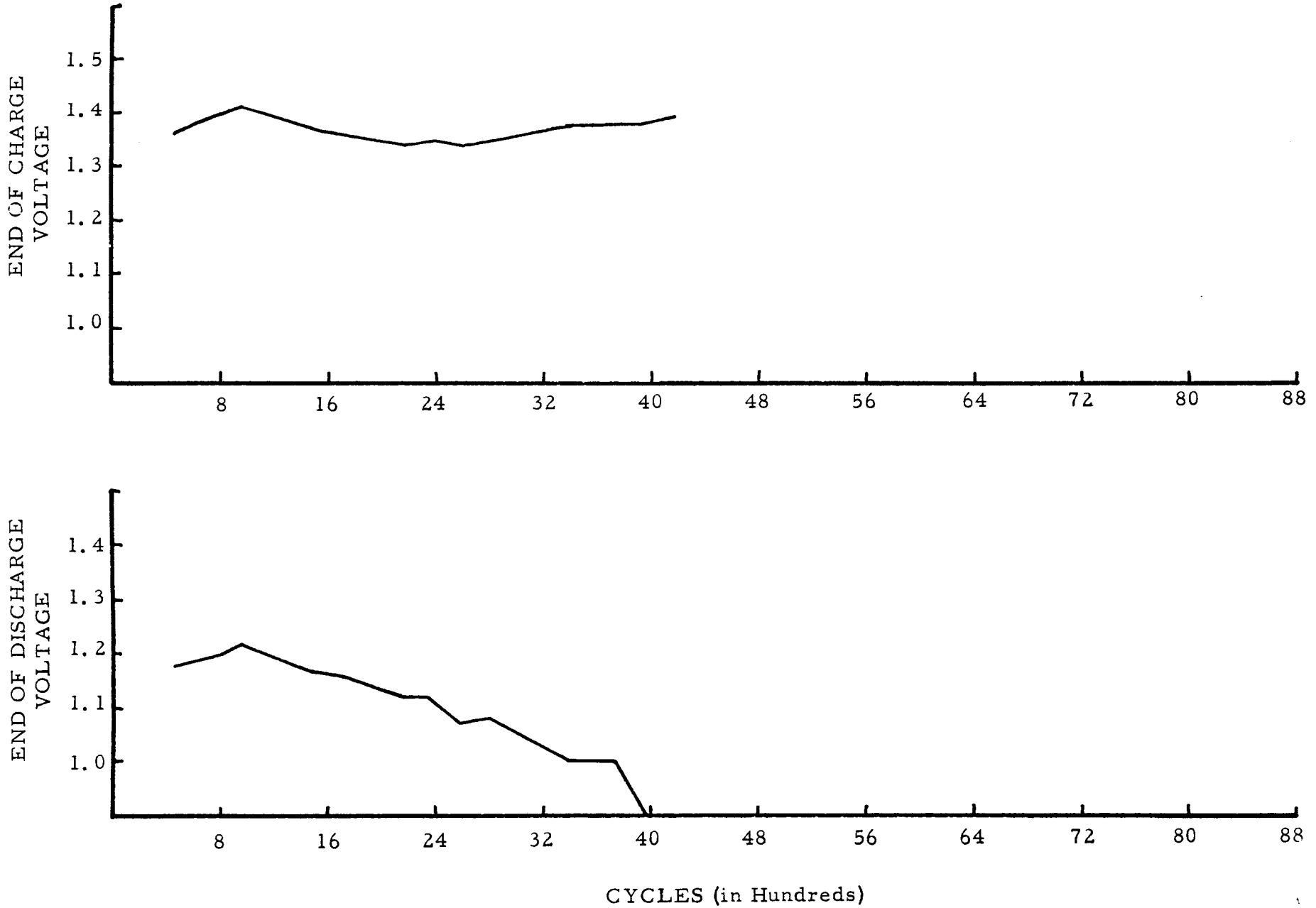
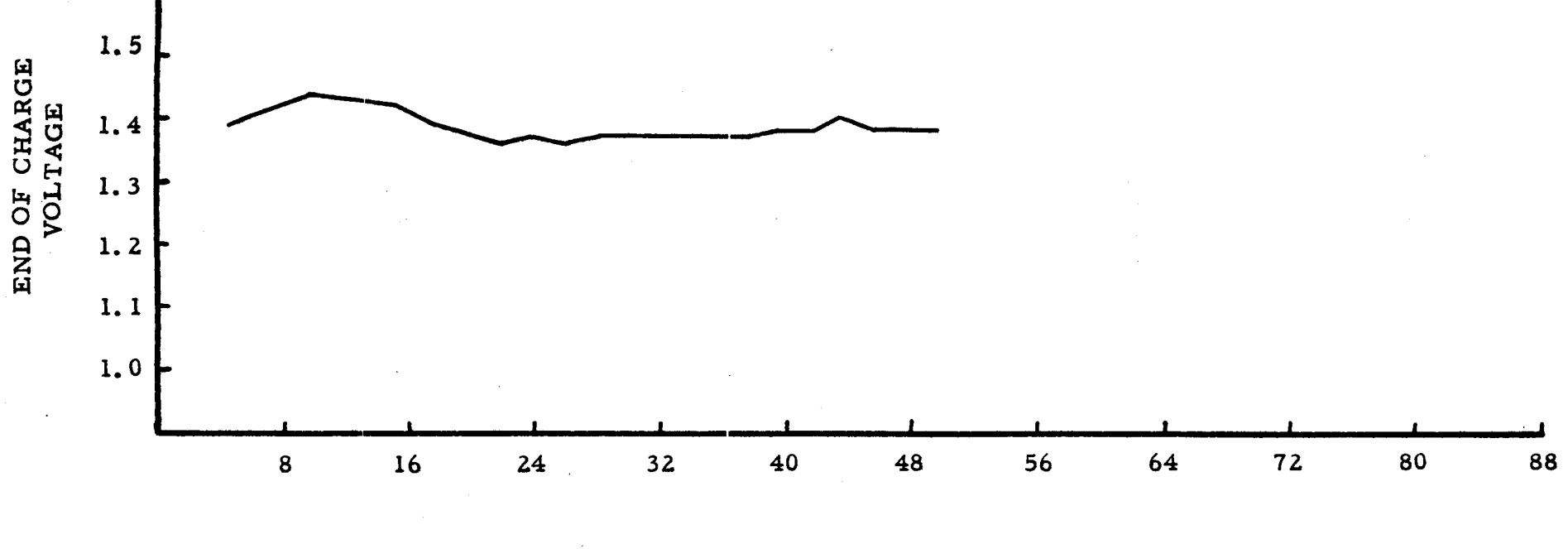


Figure 11 - Endpoint Voltage Characteristics - Cell #R48
Cycle Life: 10% Discharge at 50°C
Sonotone Cell



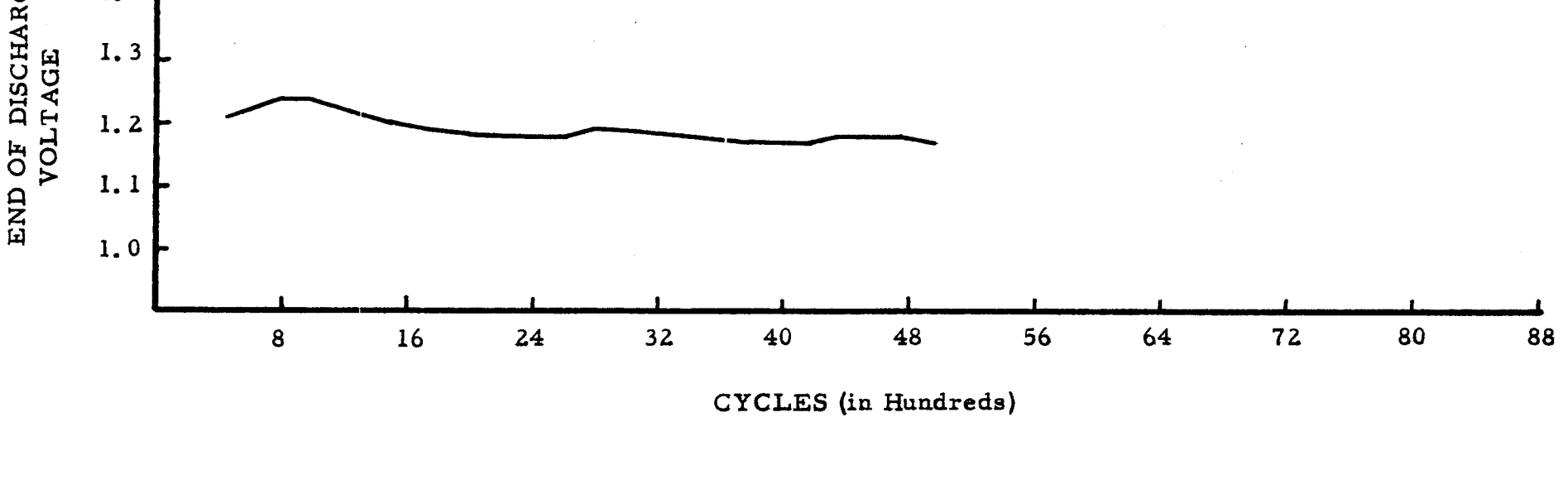


Figure 12 - Endpoint Voltage Characteristics - Cell #R49
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

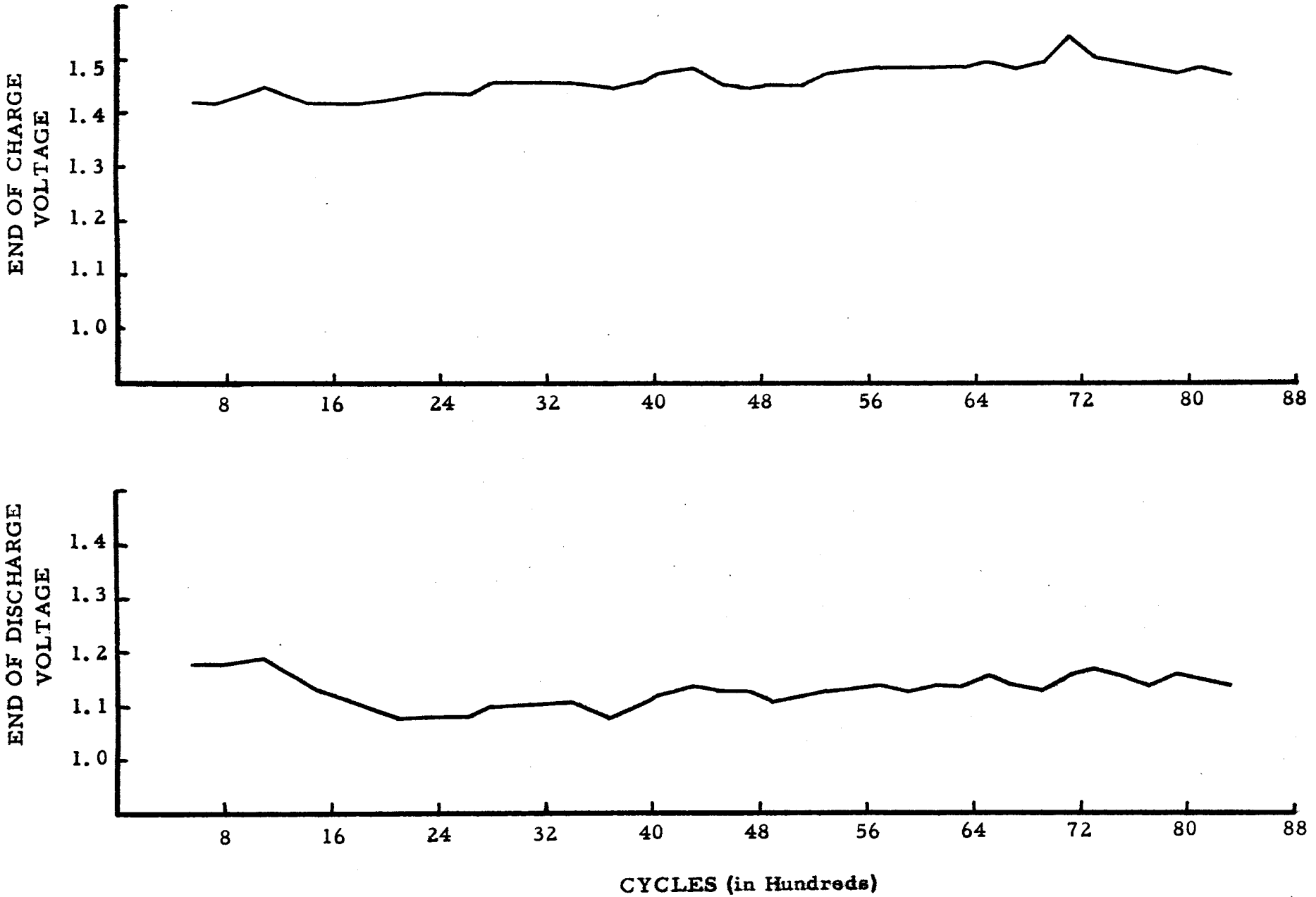


Figure 13 - Endpoint Voltage Characteristics - Cell #R56
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

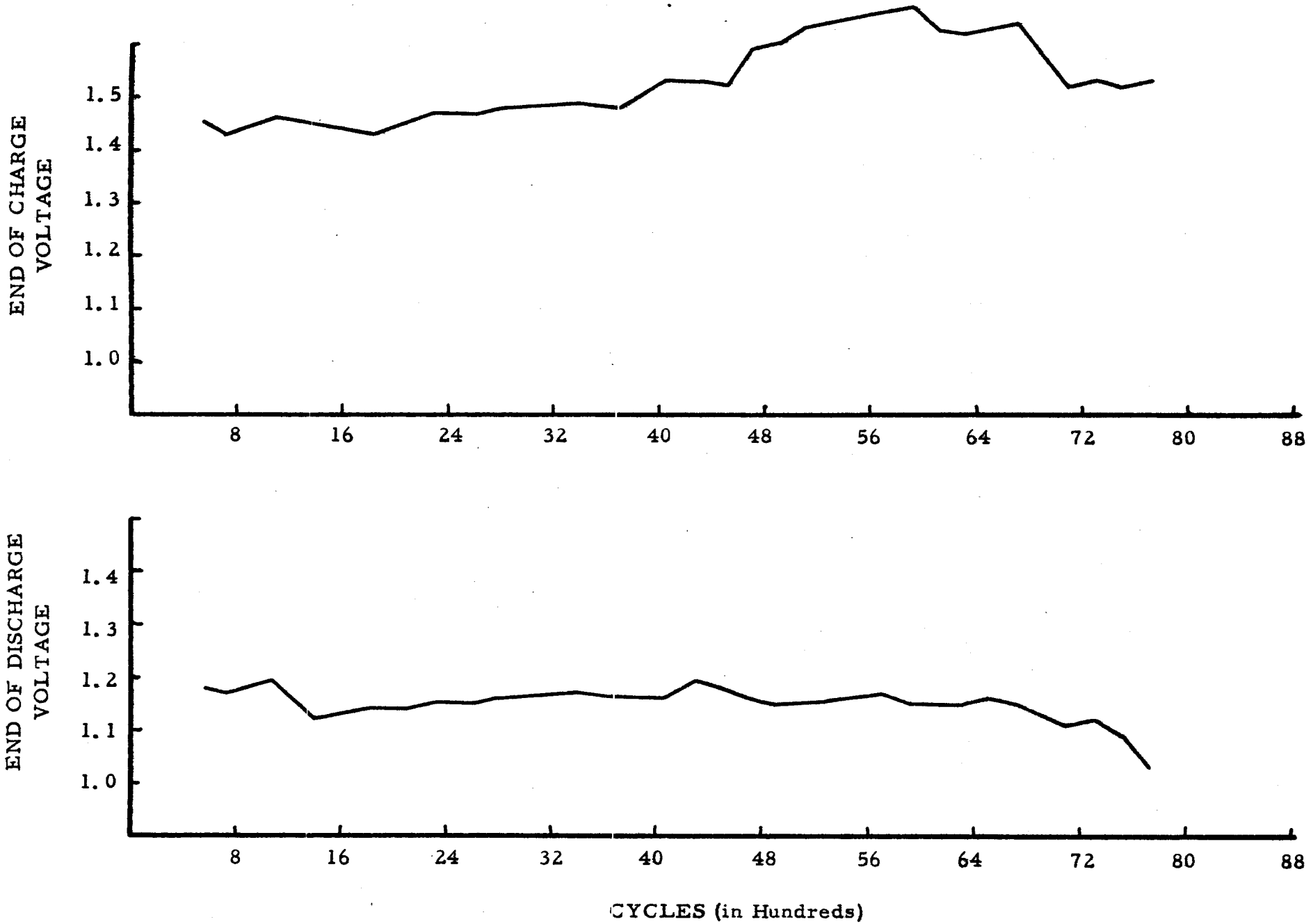


Figure 14 - Endpoint Voltage Characteristics - Cell #58
Cycle Life: 40% Discharge at 25°C
Sonotone Cell

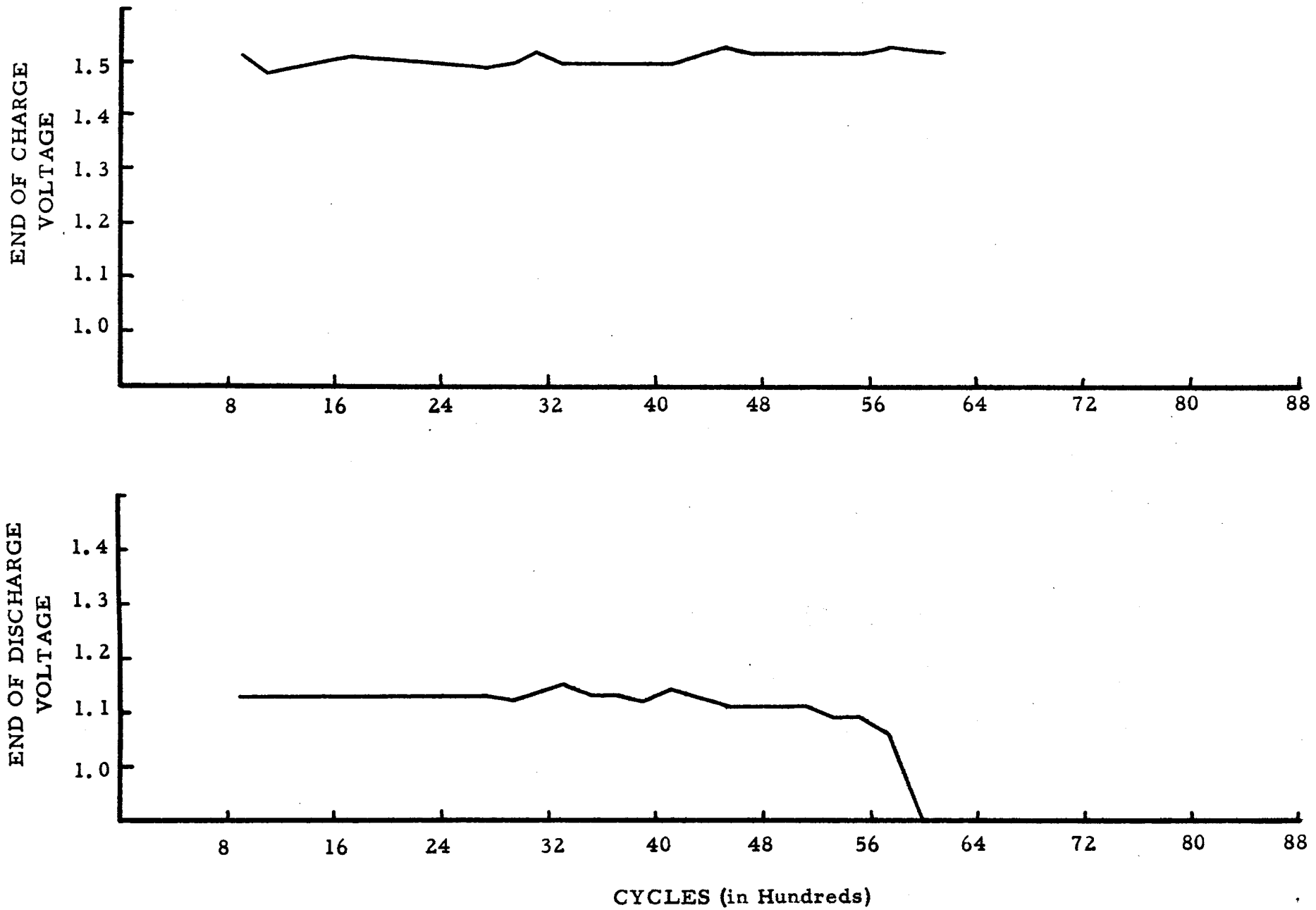


Figure 15 - Charge-Discharge Voltage Characteristics - Cell #54
Cycle Life: 10% Discharge at -10°C
Sonotone Cell

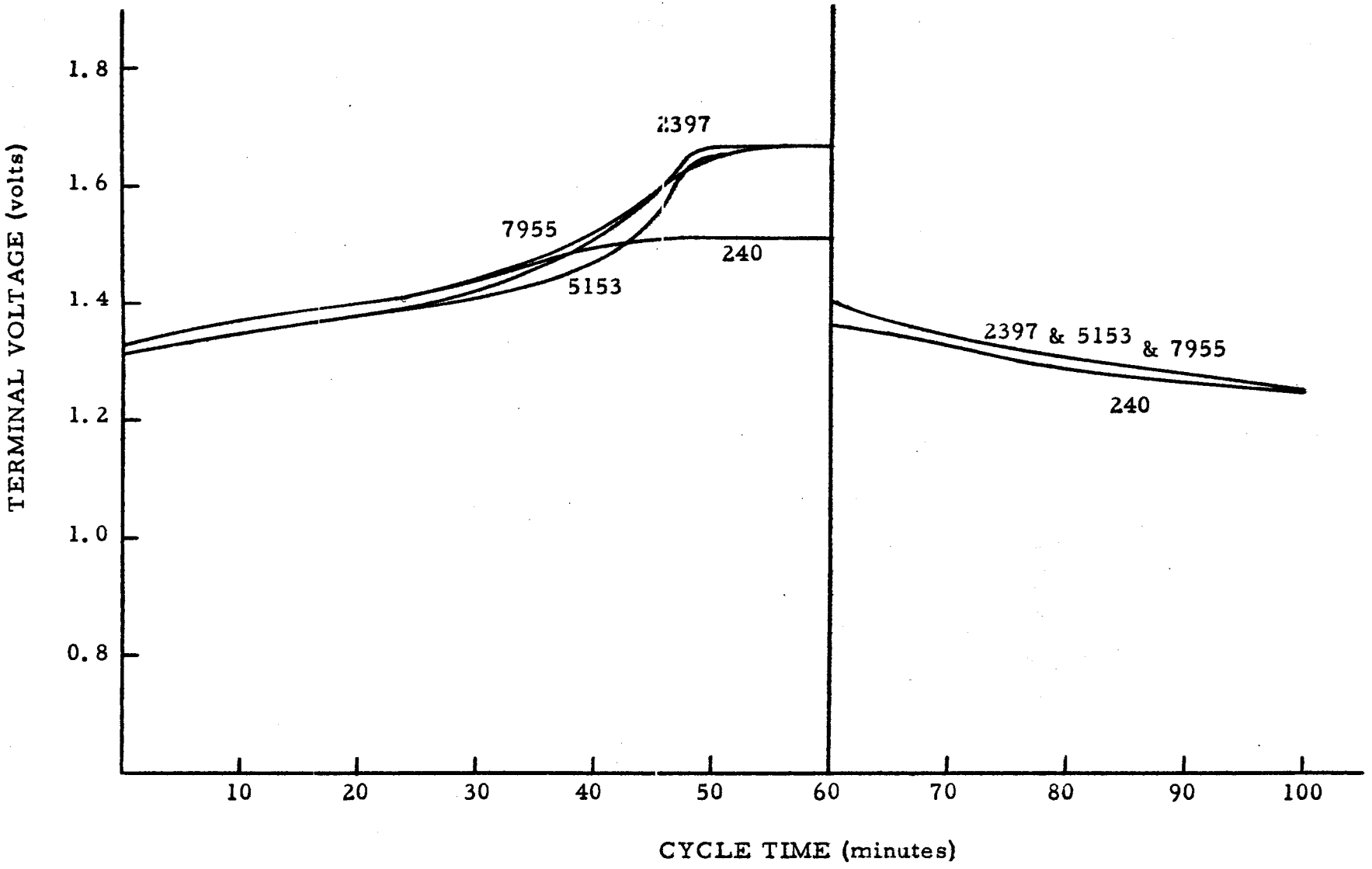


Figure 16 - Charge-Discharge Voltage Characteristics - Cell #R38
Cycle Life: 10% Discharge at -10°C
Sonotone Cell

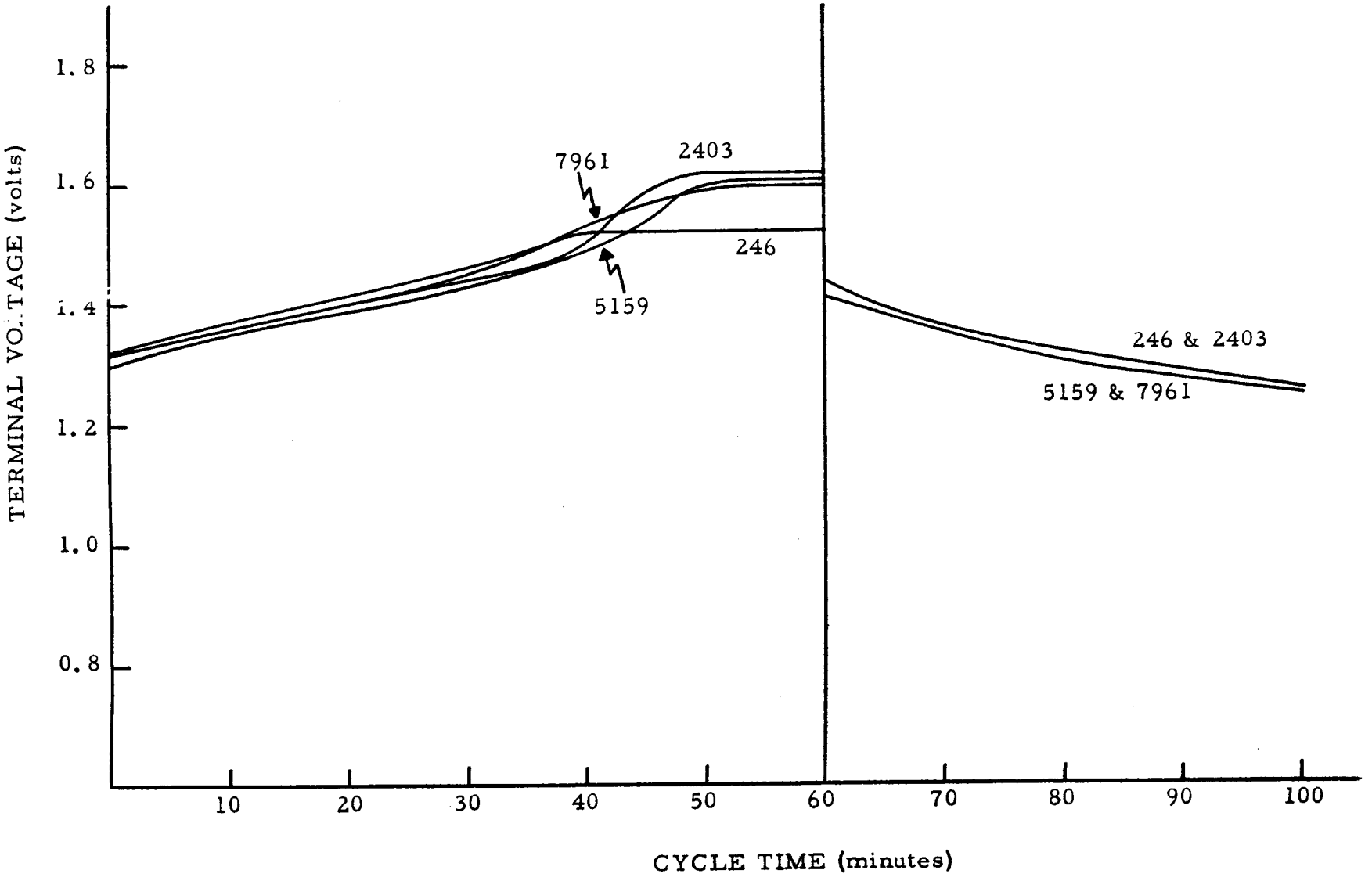


Figure 17 - Charge-Discharge Voltage Characteristics - Cell #74
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

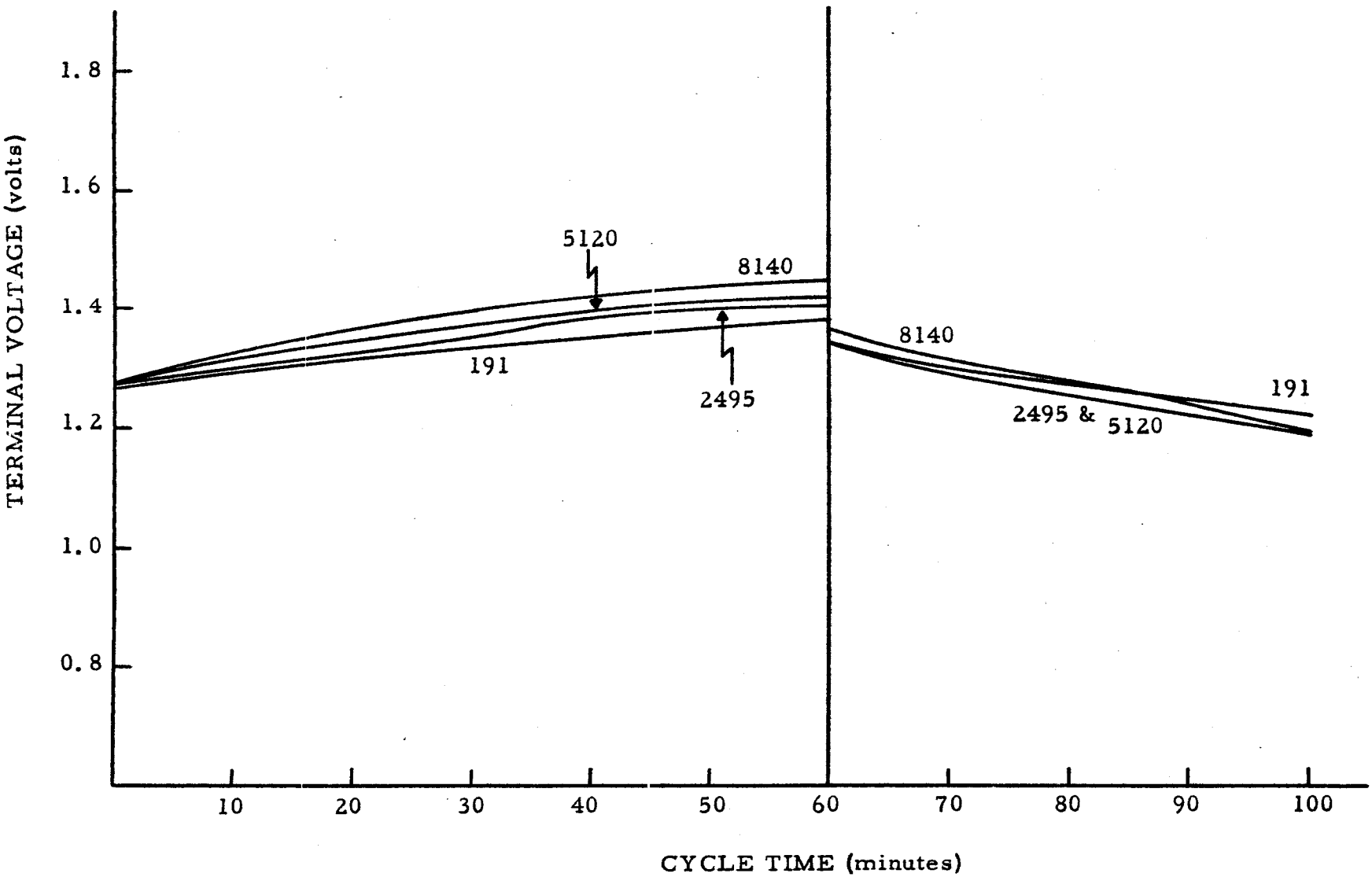


Figure 18 - Charge-Discharge Voltage Characteristics - Cell #R39
Cycle Life: 10% Discharge at 25°C
Sonotone Cell

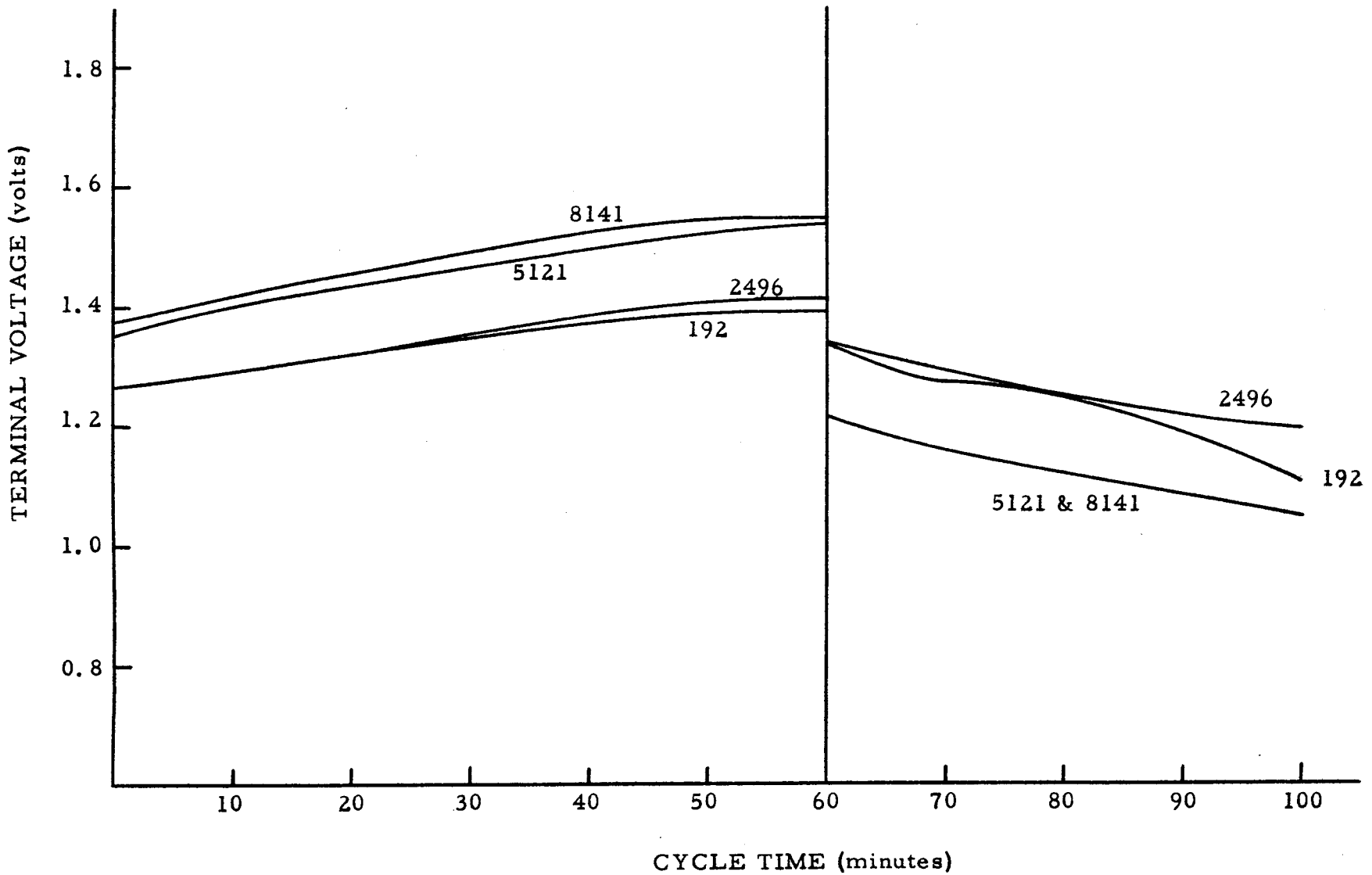


Figure 19 - Charge-Discharge Voltage Characteristics - Cell #75
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

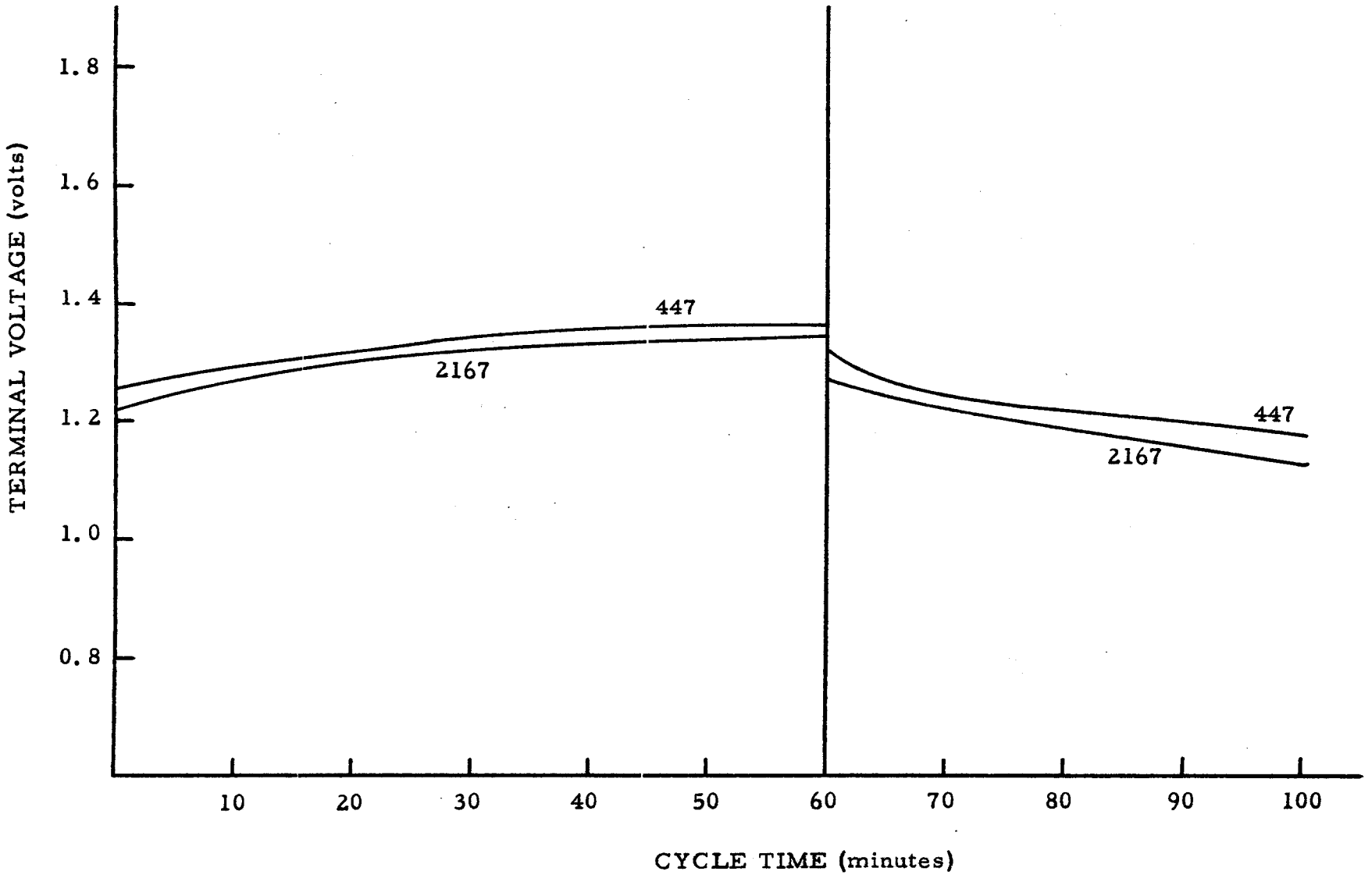


Figure 20 - Charge-Discharge Voltage Characteristics - Cell #R48
Cycle Life: 10% Discharge at 50°C
Sonotone Cell

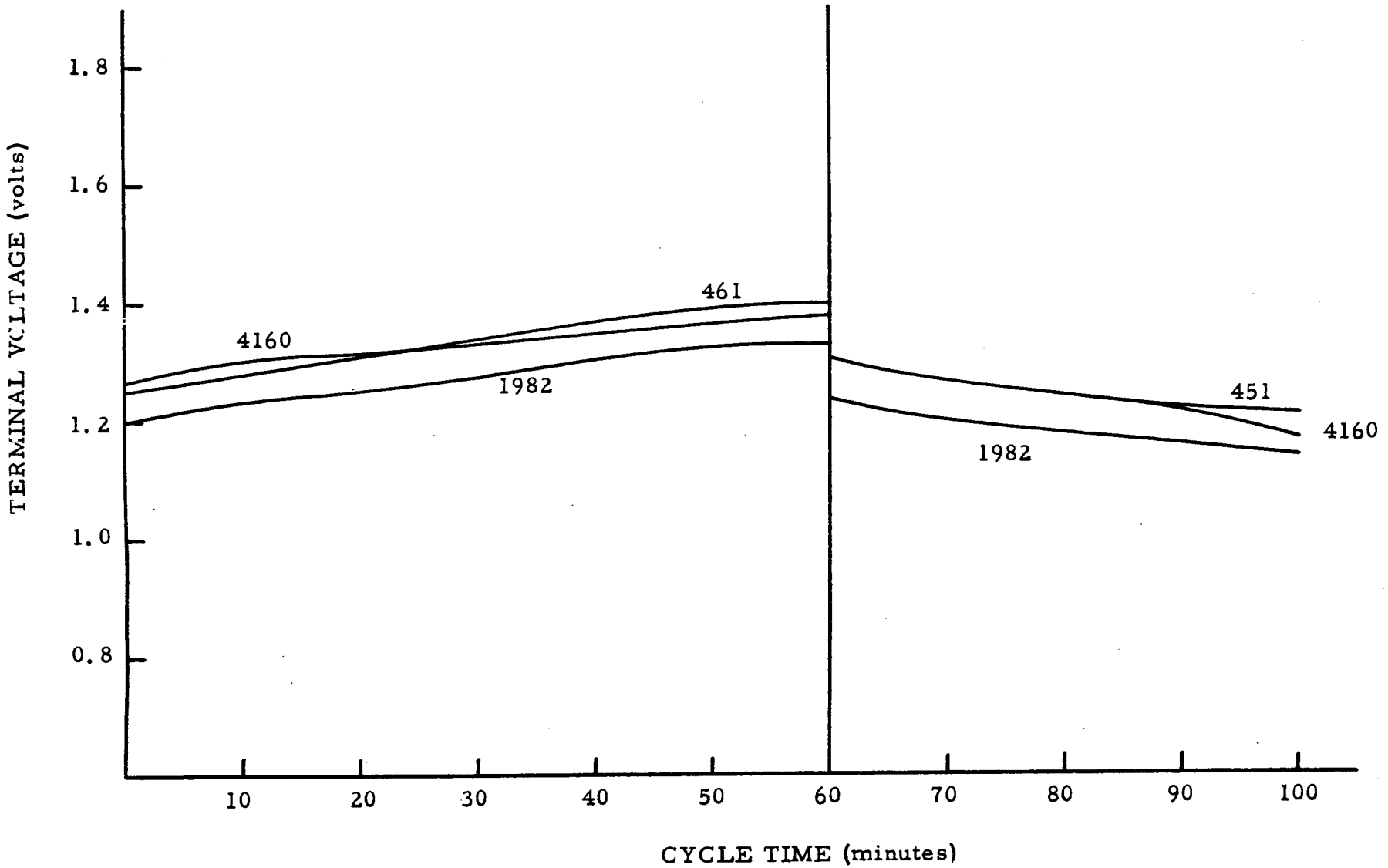


Figure 21 - Charge-Discharge Voltage Characteristics - Cell #R49
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

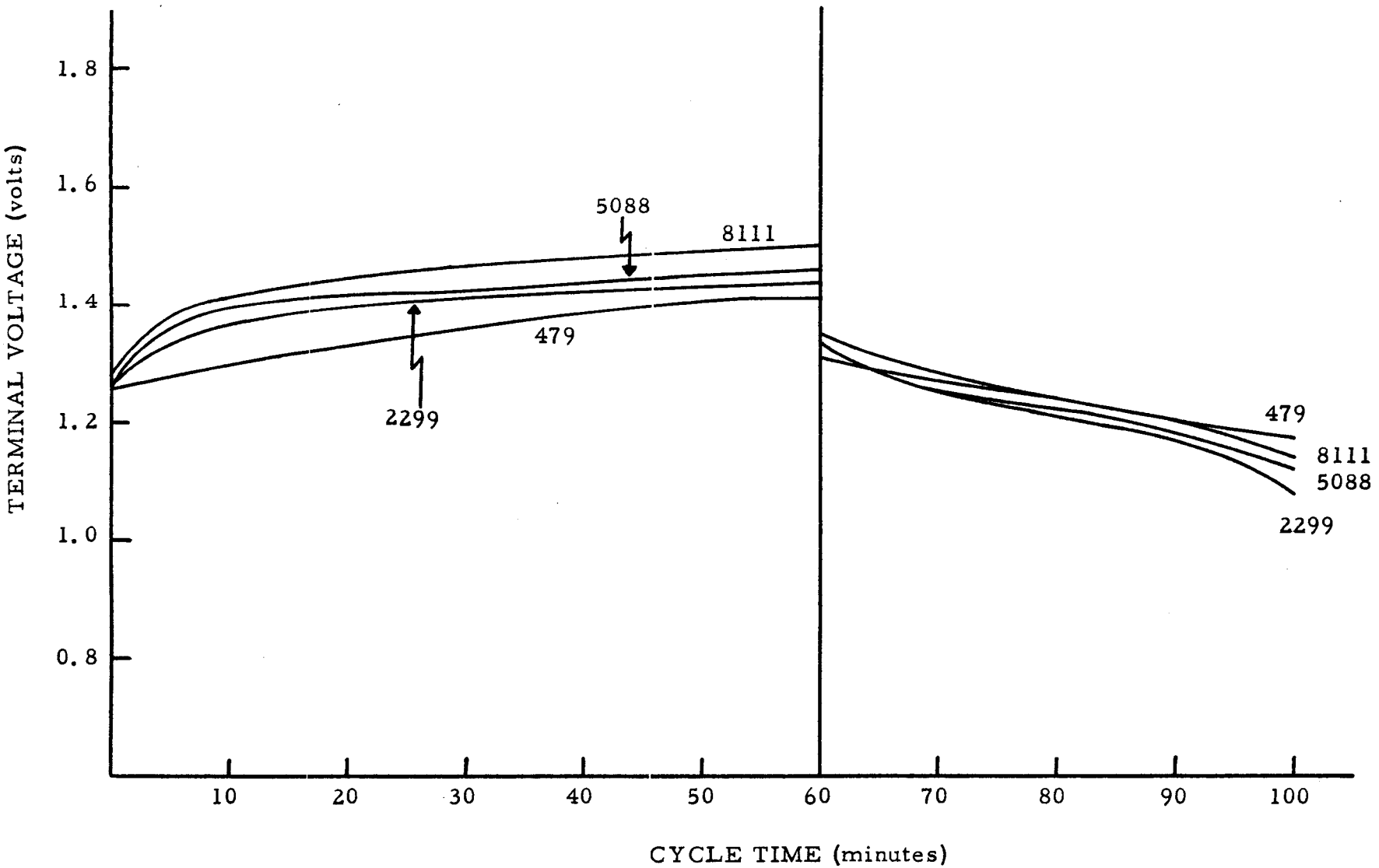


Figure 22 - Charge-Discharge Voltage Characteristics - Cell #R56
Cycle Life: 25% Discharge at 25°C
Sonotone Cell

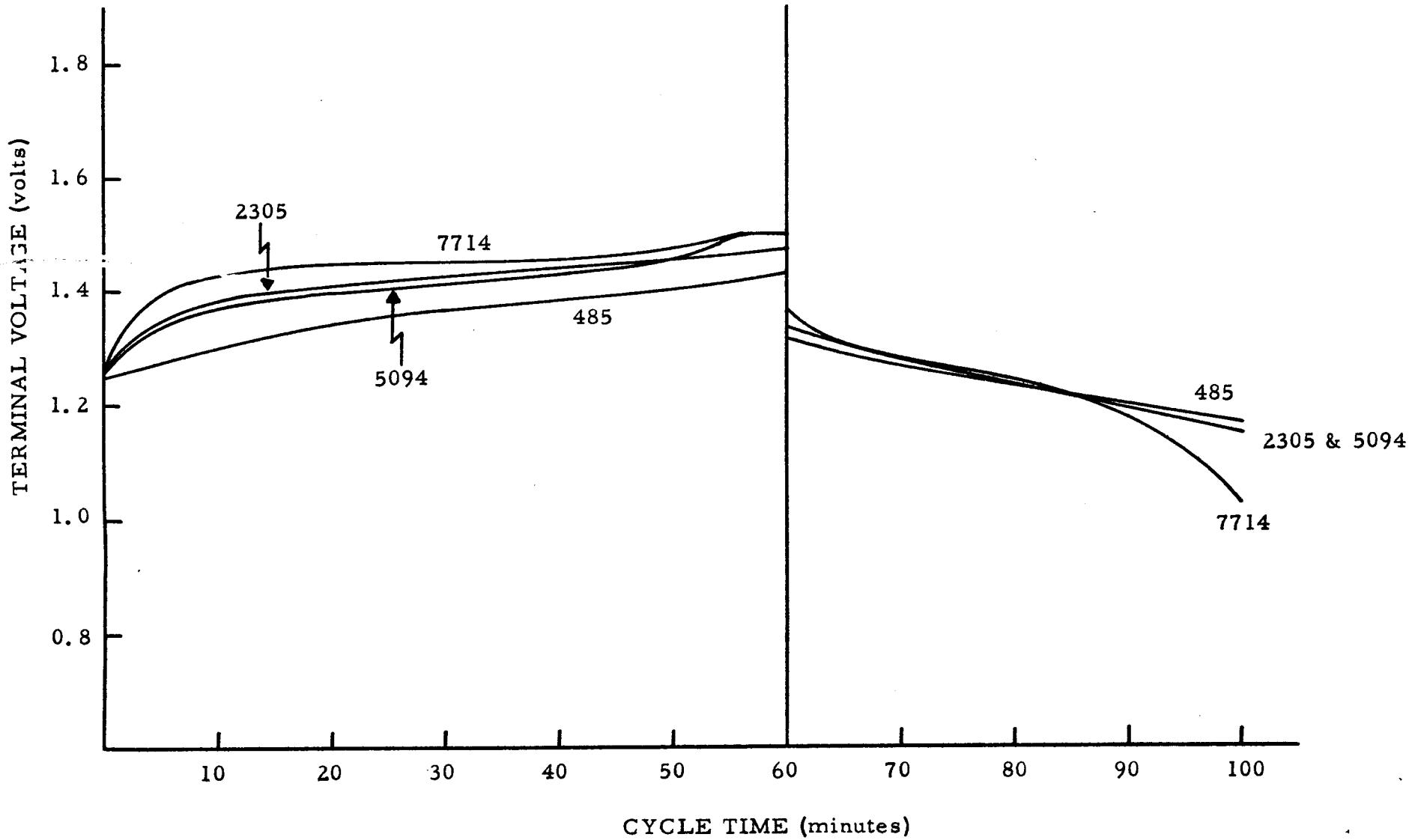


Figure 23 - Charge-Discharge Voltage Characteristics - Cell #R58
Cycle Life: 40% Discharge at 25°C
Sonotone Cell

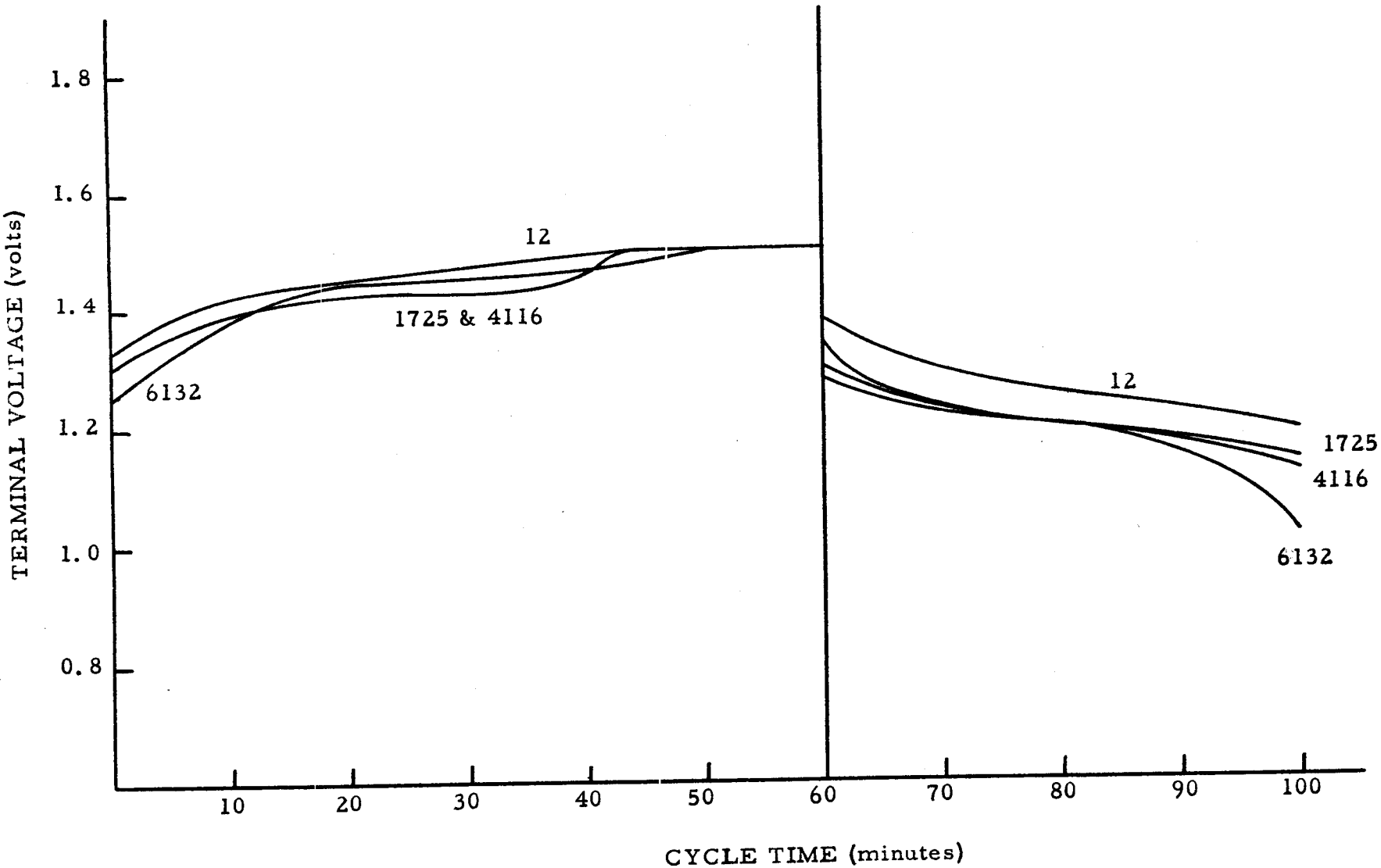


Figure 24 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at -10°C
Gould-National Cells

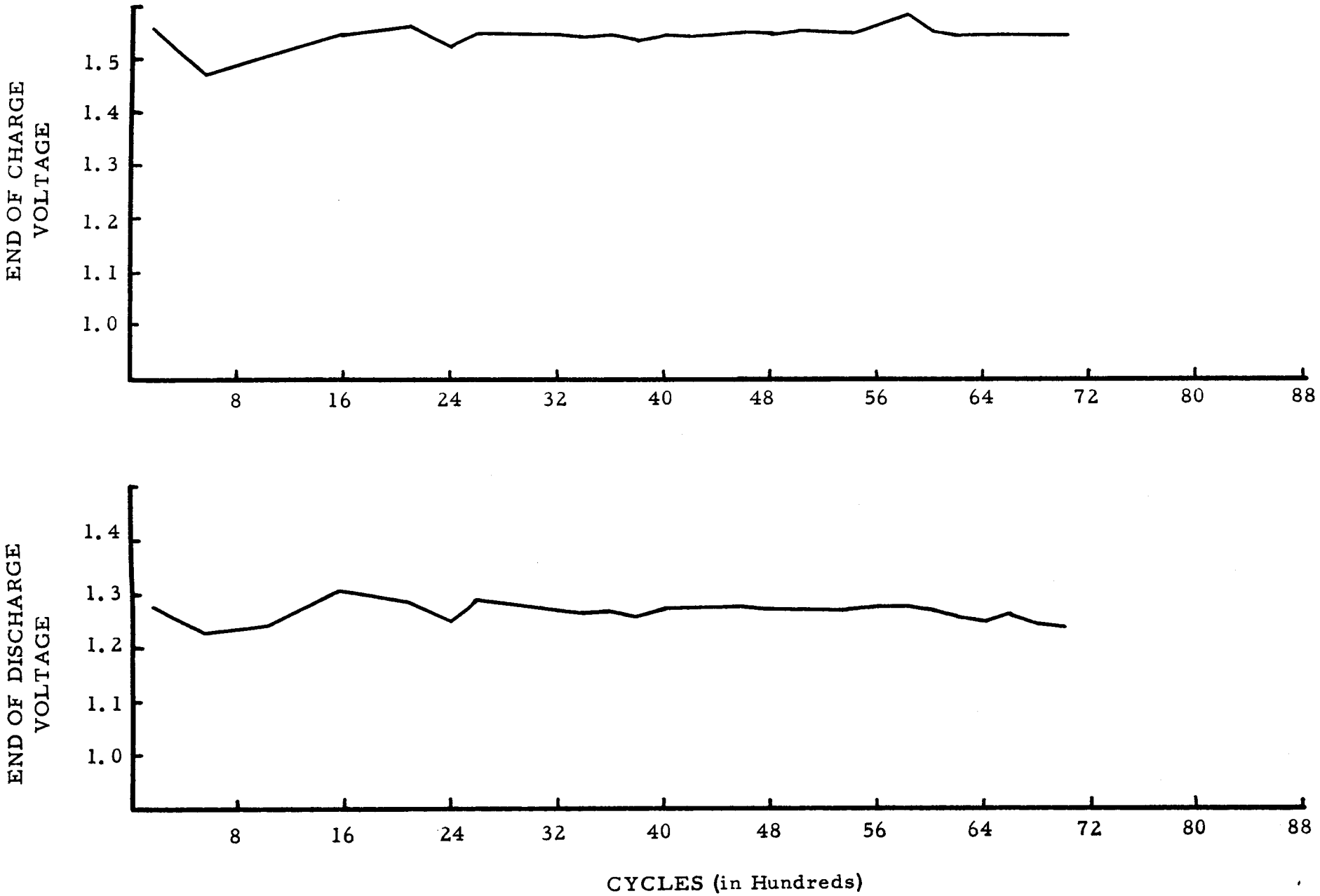


Figure 25 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 25°C
Gould-National Cells

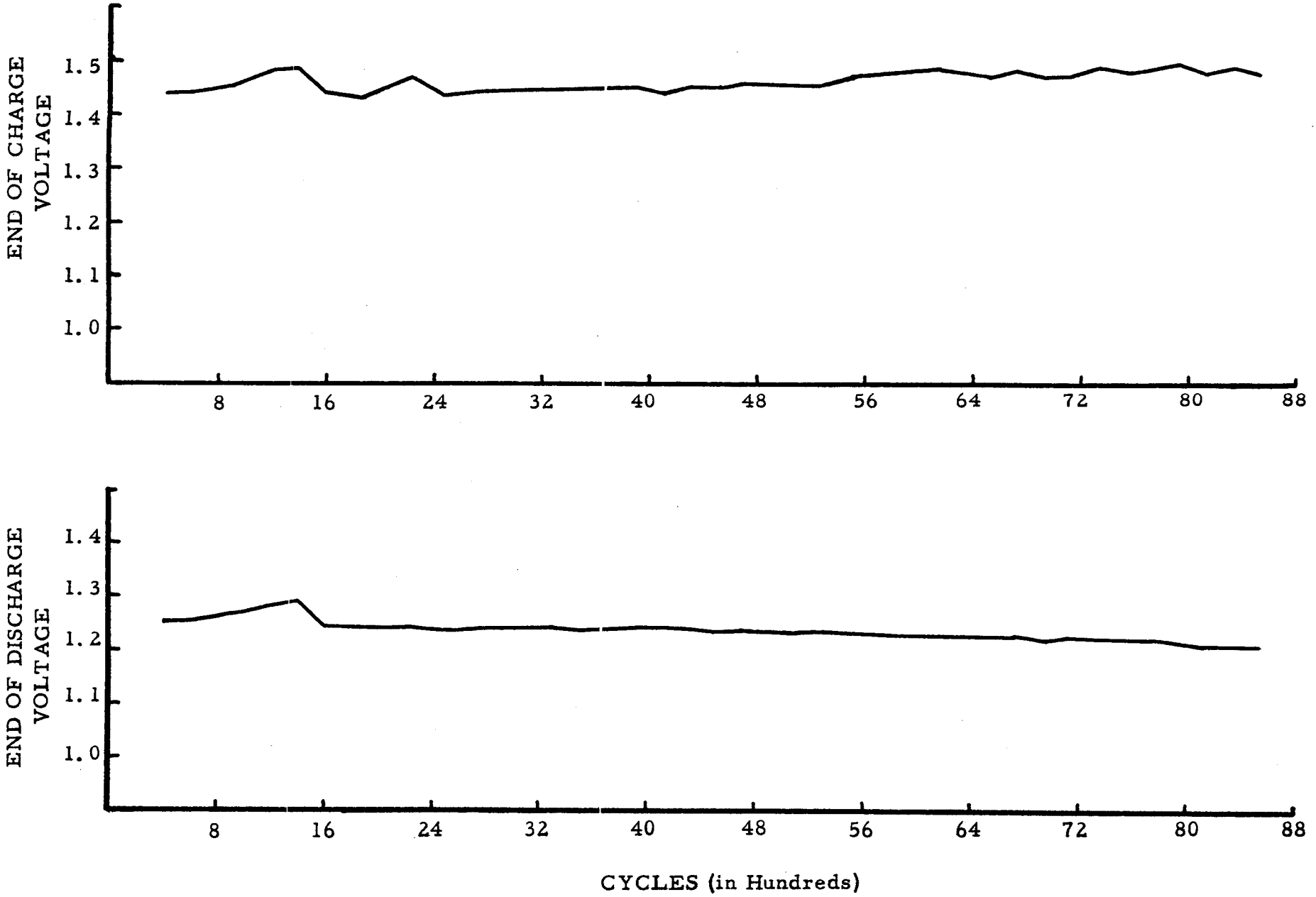


Figure 26 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 50°C
Gould-National Cells

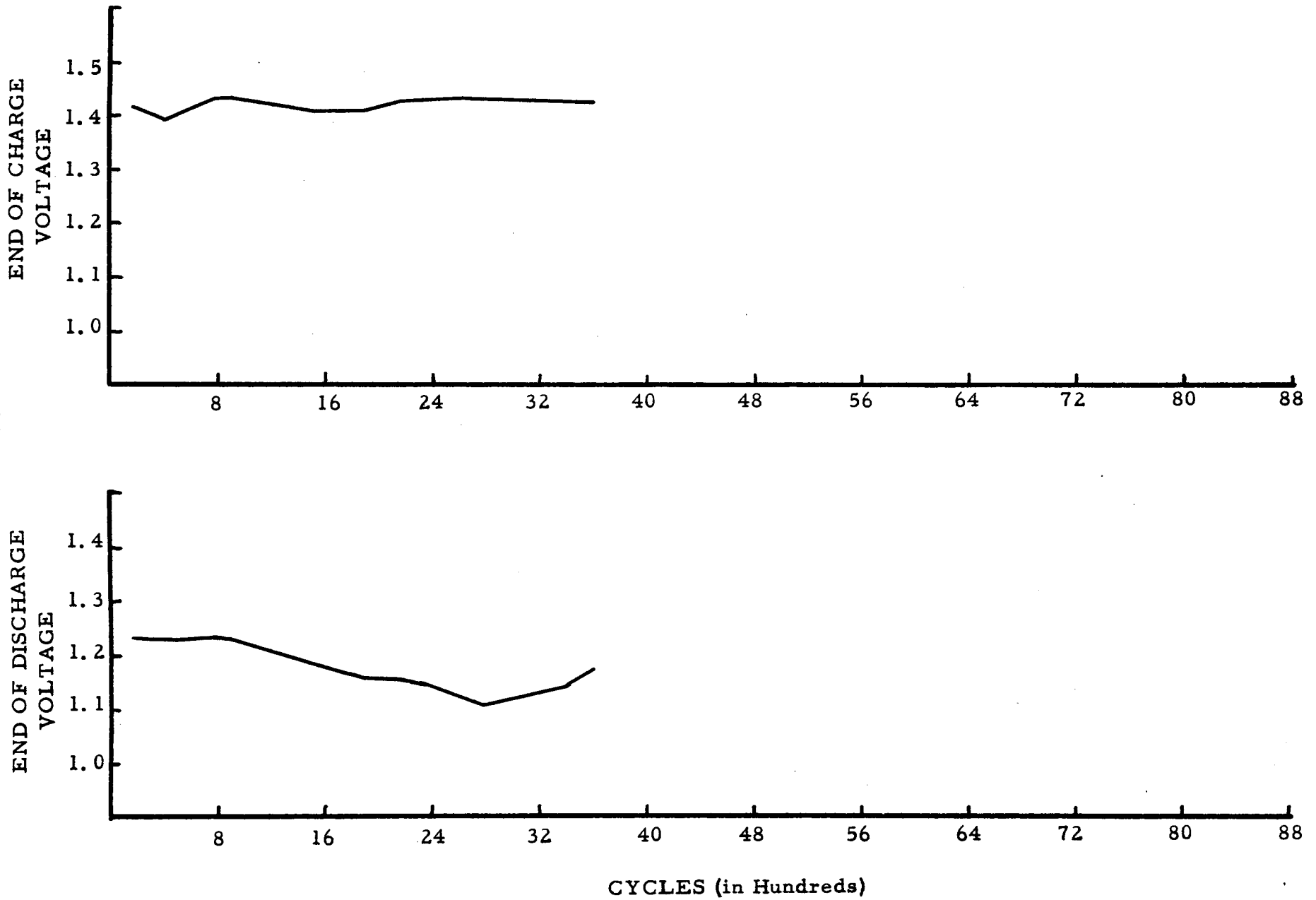


Figure 27 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 25% Discharge at 25°C
Gould-National Cells

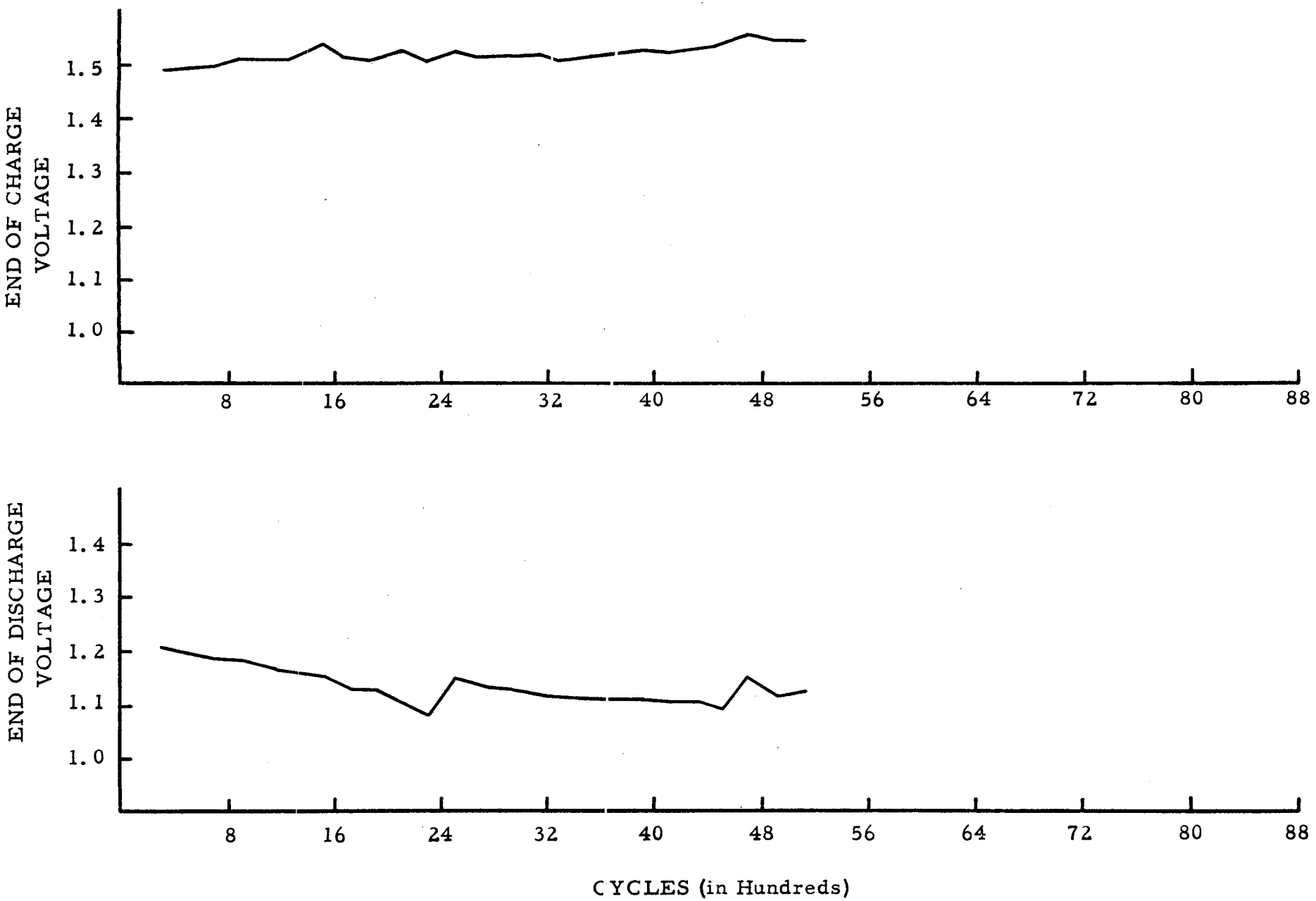


Figure 28 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 40% Discharge at 25°C
Gould-National Cell

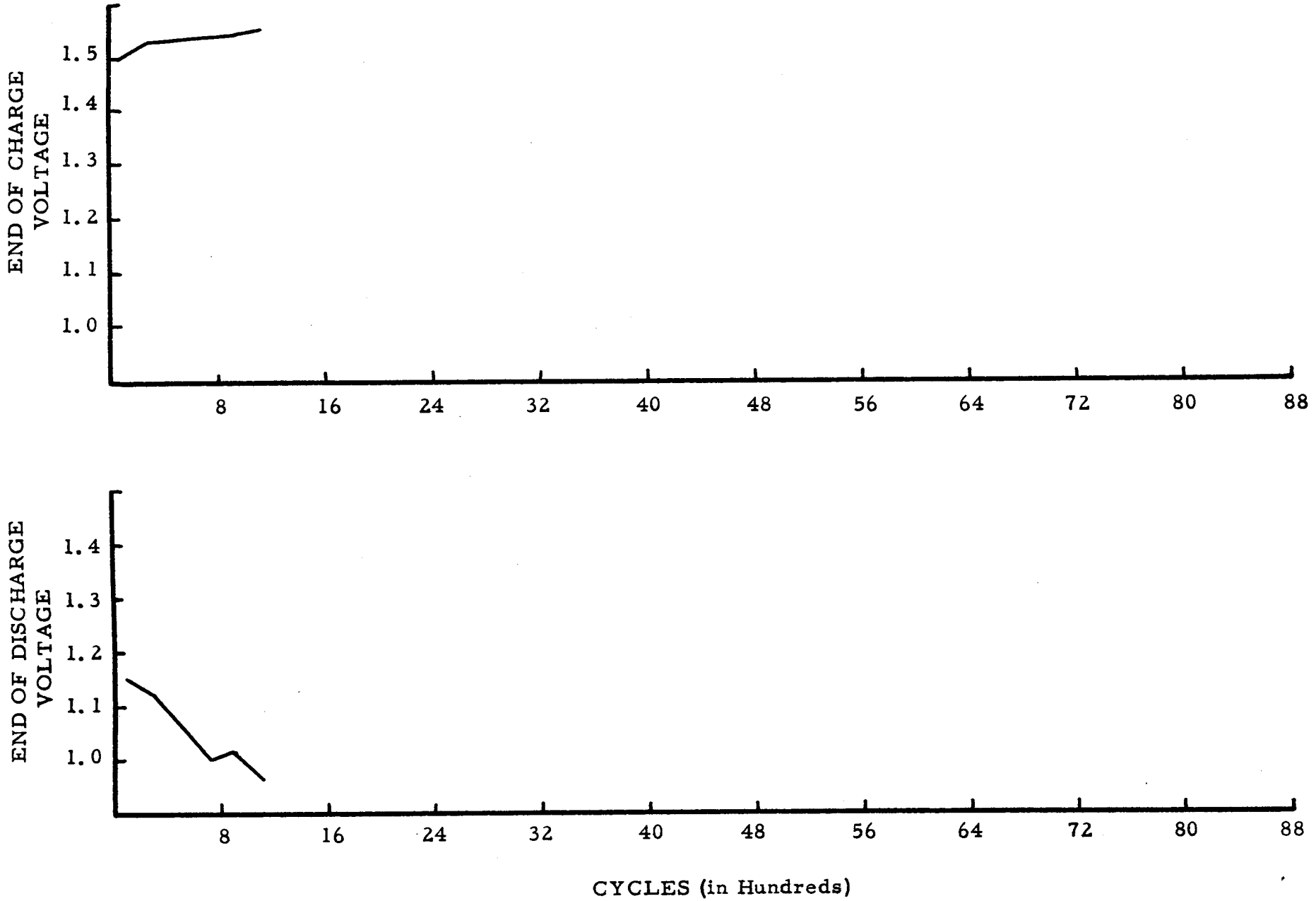


Figure 29 - Endpoint Voltage Characteristics - Cell #35
Cycle Life: 10% Discharge at -10°C
Gould-National Cell

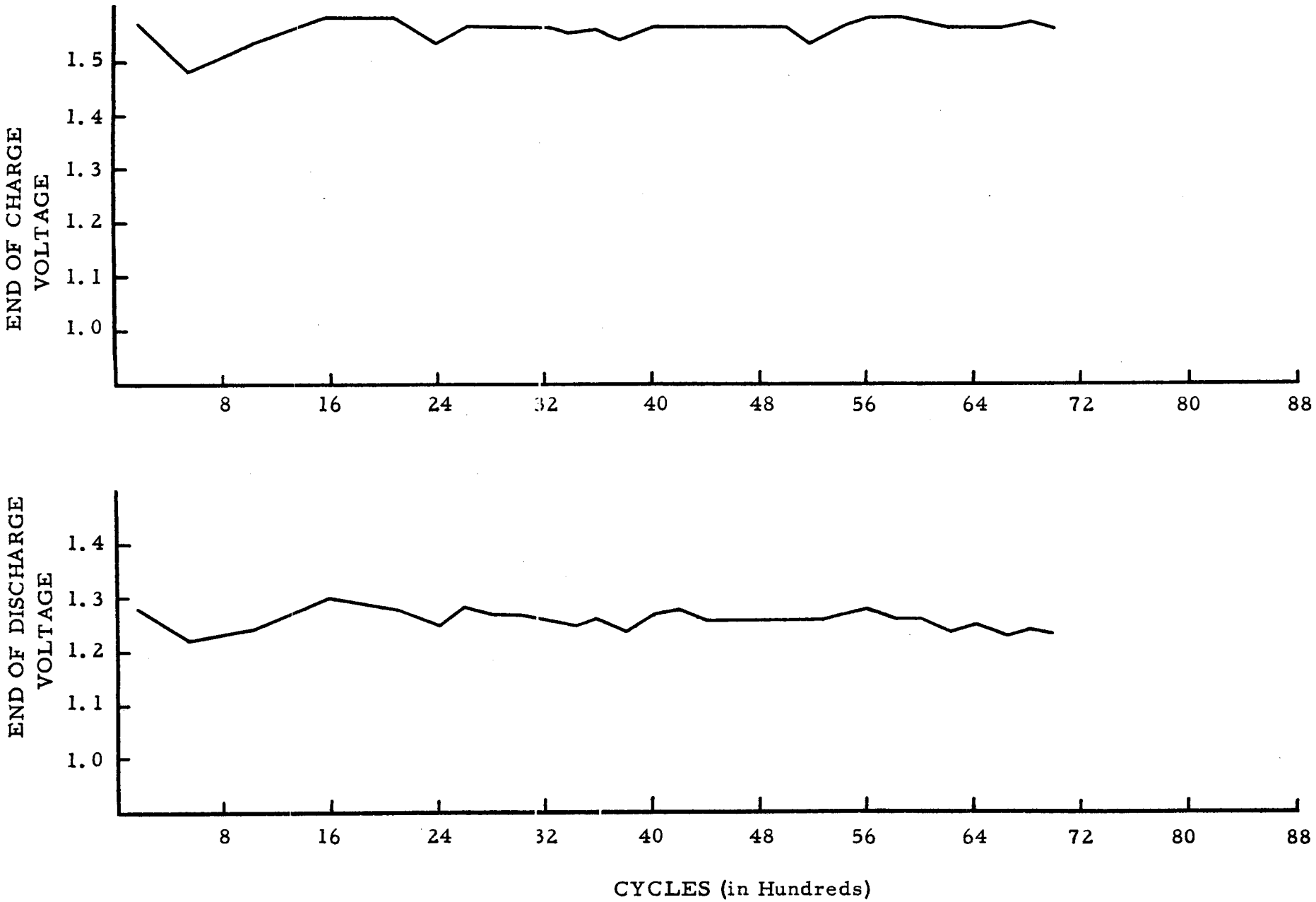


Figure 30 - Endpoint Voltage Characteristics - Cell #9
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

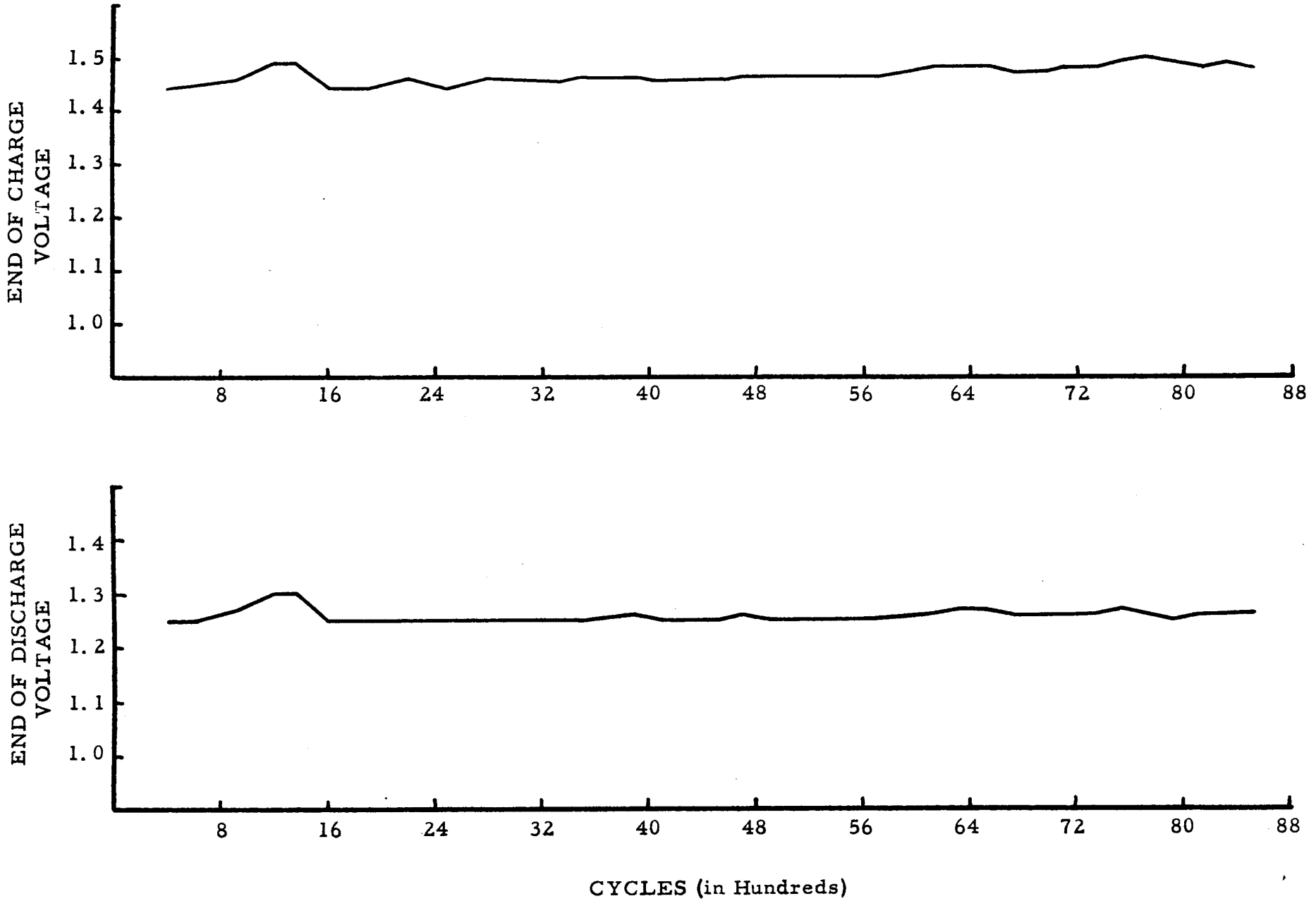


Figure 31 - Endpoint Voltage Characteristics - Cell #22
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

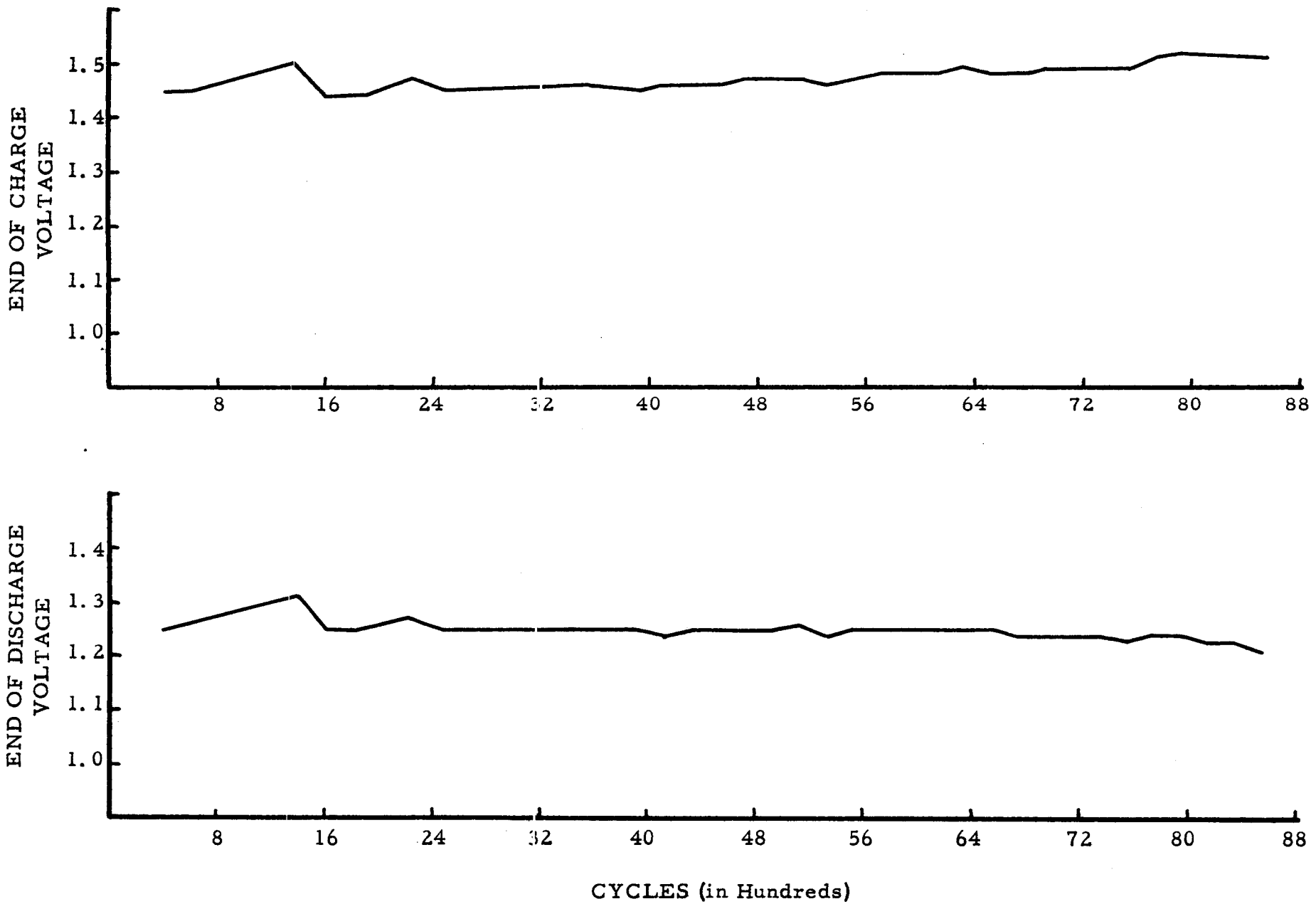


Figure 32 - Endpoint Voltage Characteristics - Cell #21
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

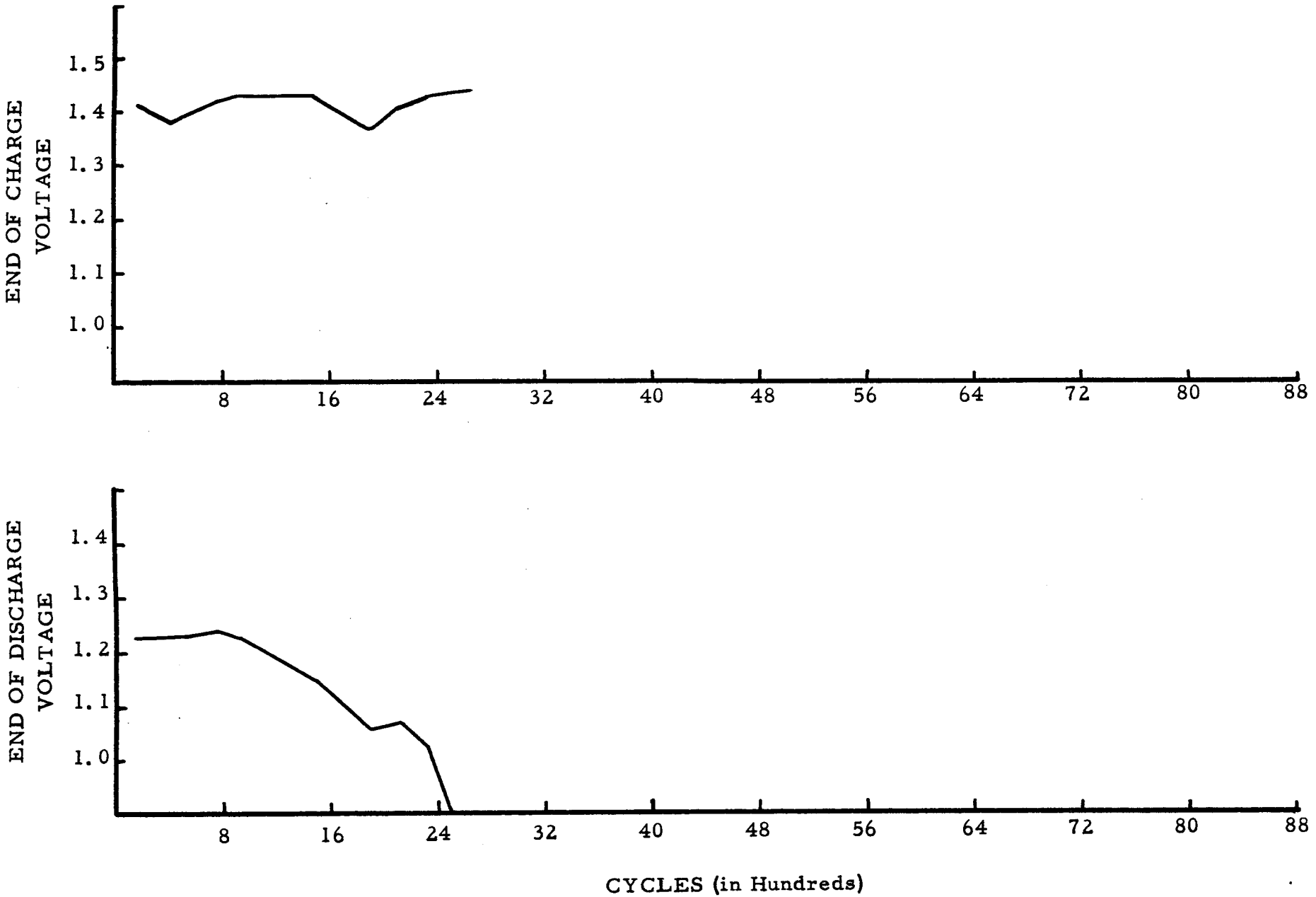


Figure 33 - Endpoint Voltage Characteristics - Cell #28
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

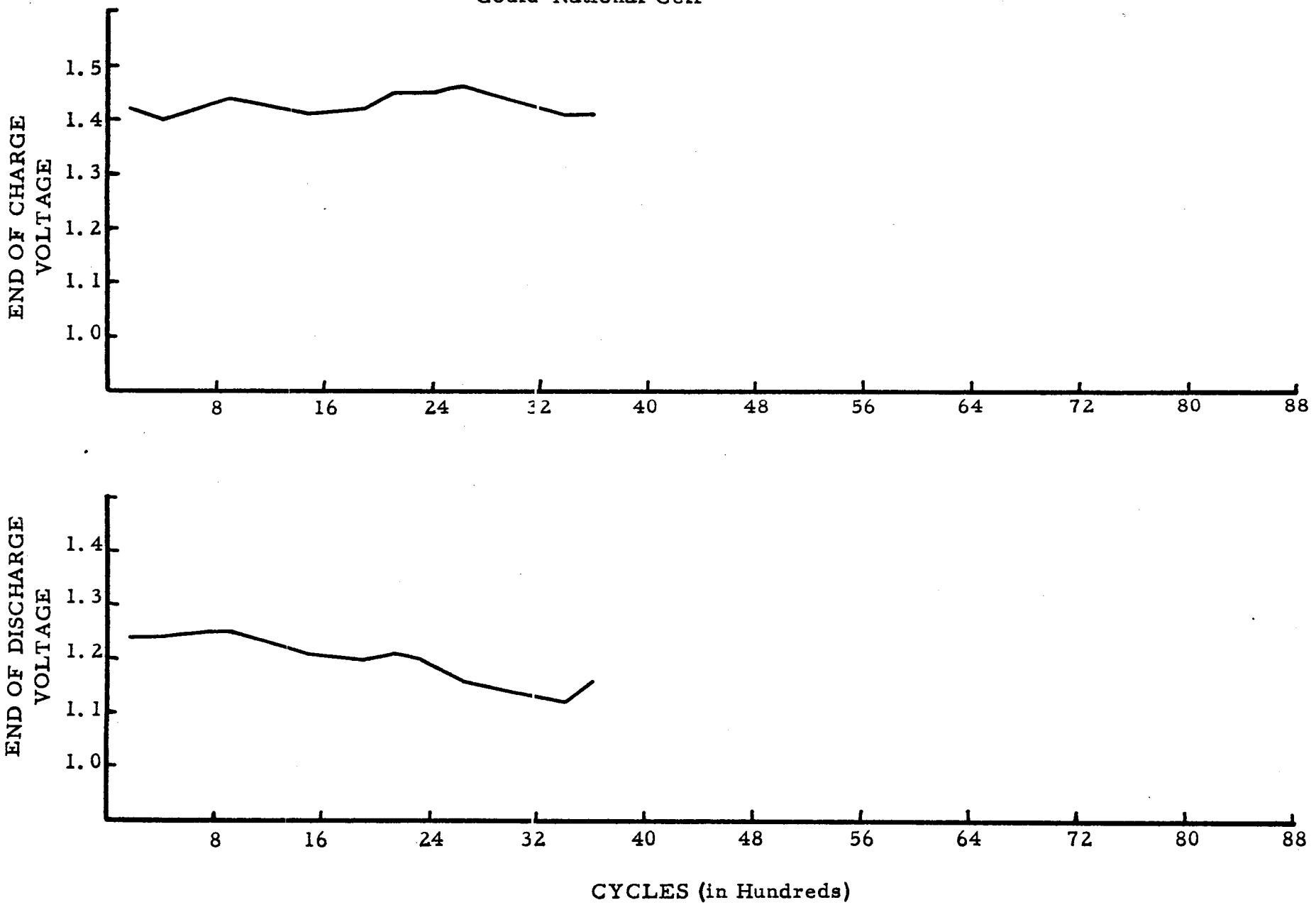


Figure 34 - Endpoint Voltage Characteristics - Cell #3
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

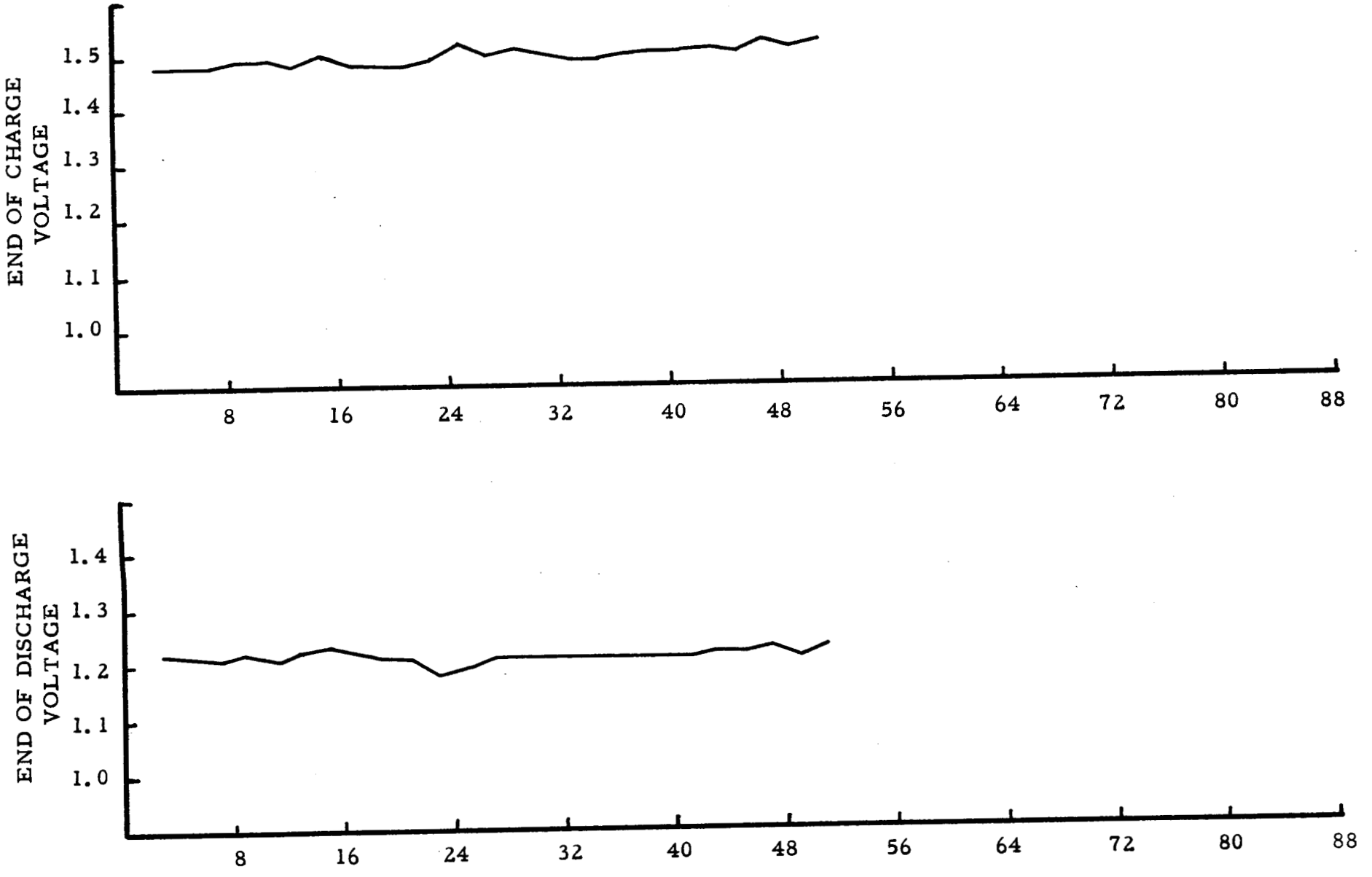


Figure 35 - Endpoint Voltage Characteristics - Cell #13
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

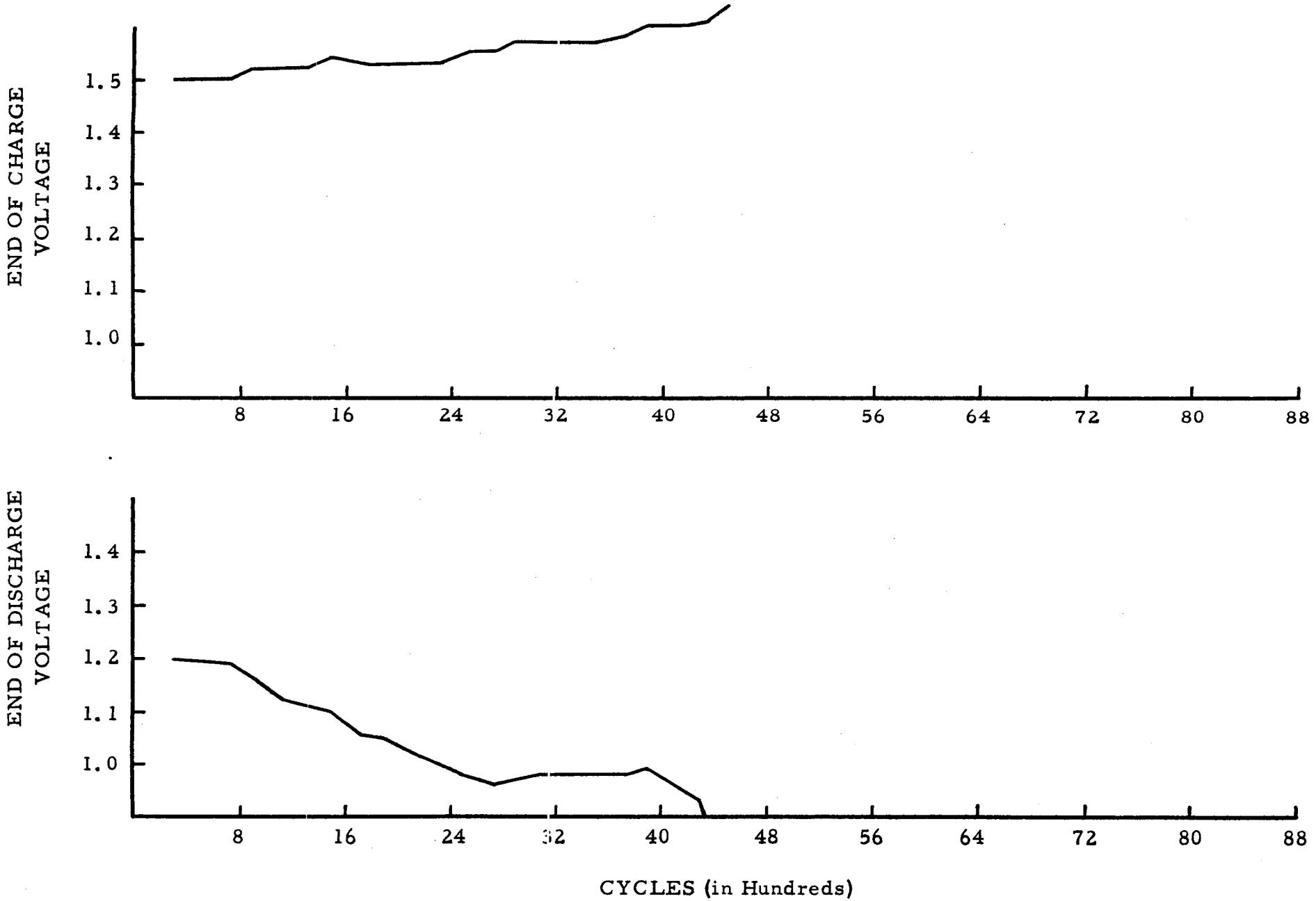


Figure 36 - Endpoint Voltage Characteristics - Cell #49
Cycle Life: 40% Discharge at 25°C
Gould-National Cell

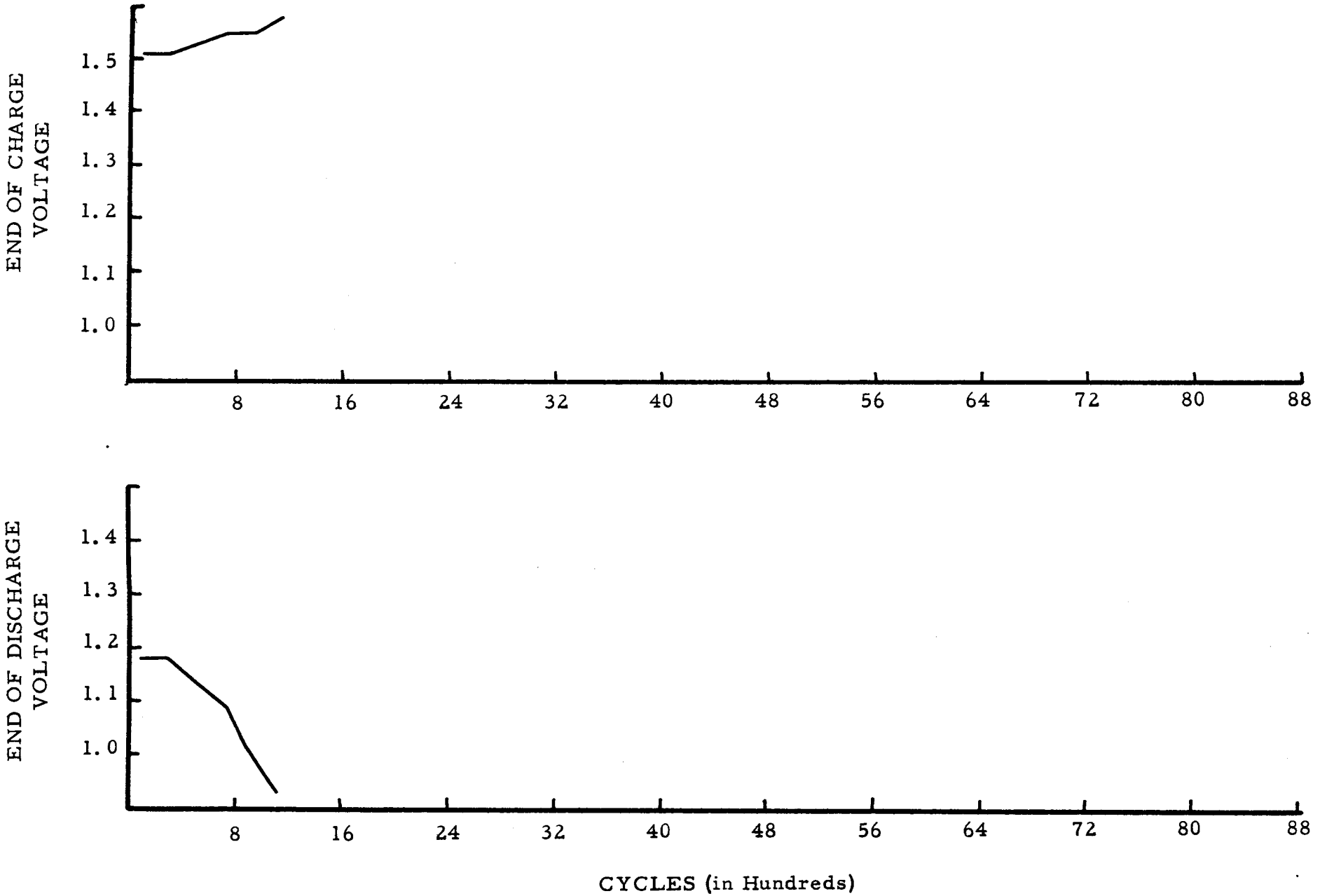


Figure 37 - Charge-Discharge Voltage Characteristics - Cell #35
Cycle Life: 10% Discharge at -10°C
Gould-National Cell

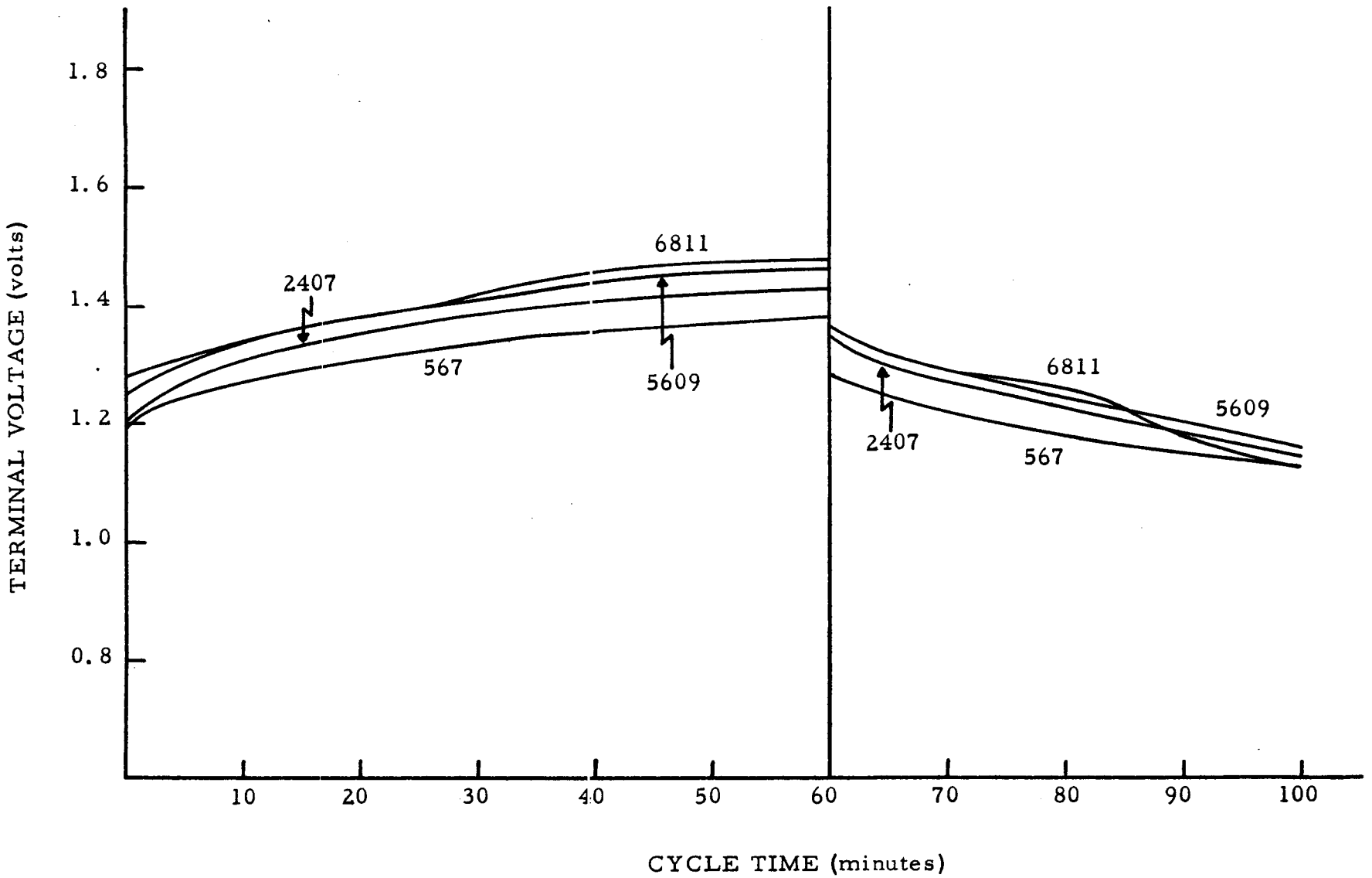


Figure 38 - Charge-Discharge Voltage Characteristics - Cell #9
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

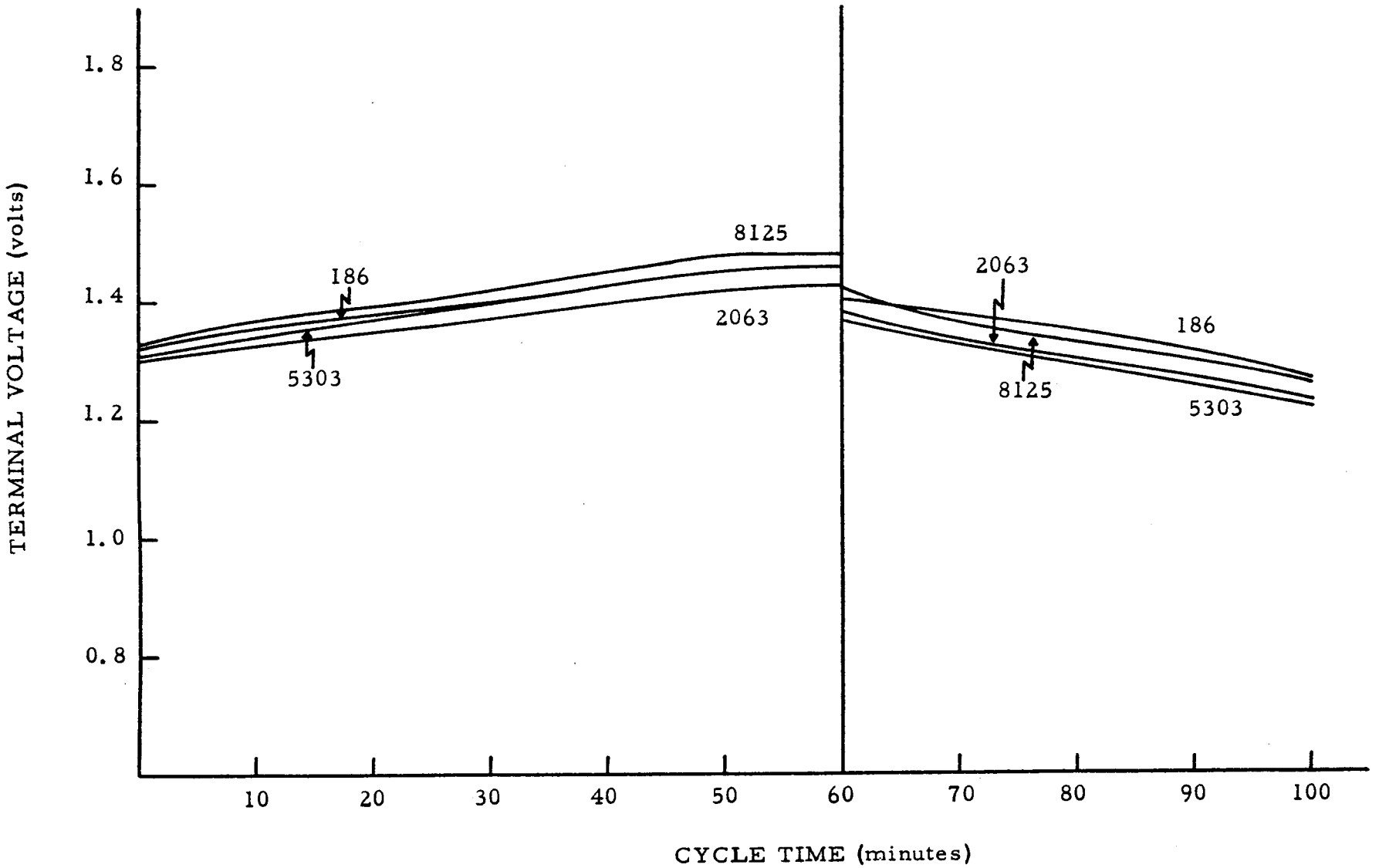


Figure 39 - Charge-Discharge Voltage Characteristics - Cell #22
Cycle Life: 10% Discharge at 25°C
Gould-National Cell

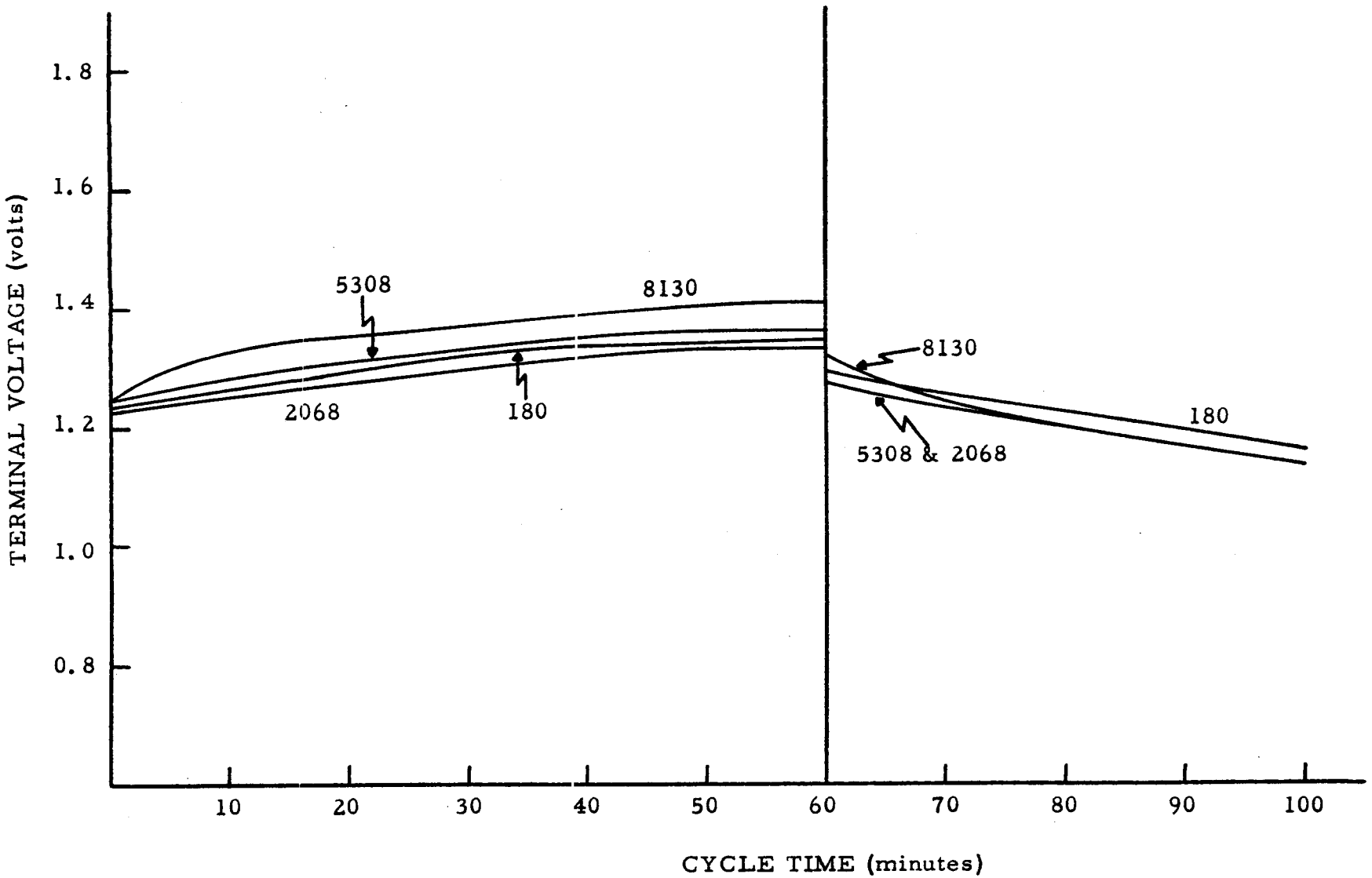


Figure 40 - Charge-Discharge Voltage Characteristics - Cell #21
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

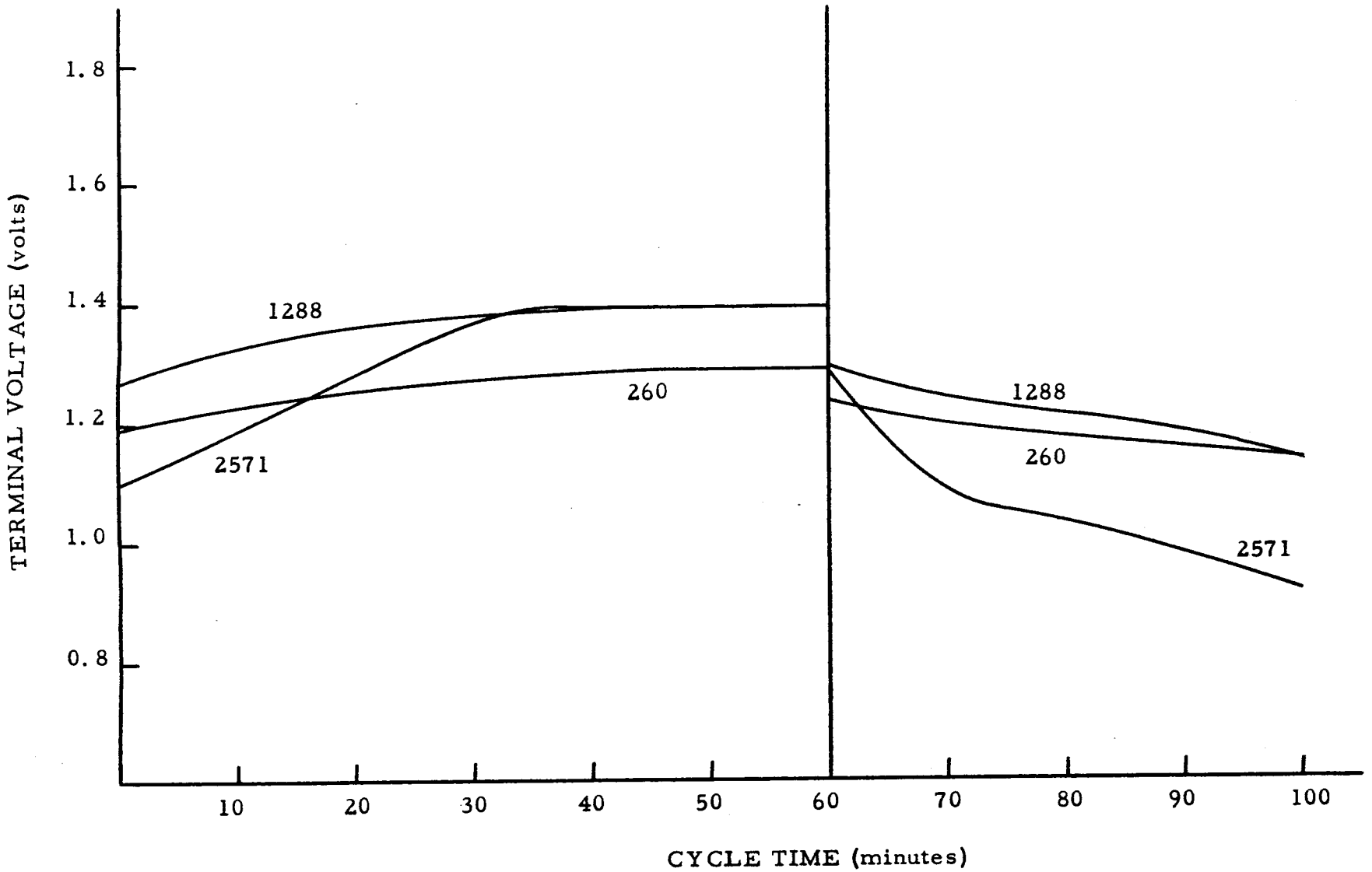


Figure 41 - Charge-Discharge Voltage Characteristics - Cell #28
Cycle Life: 10% Discharge at 50°C
Gould-National Cell

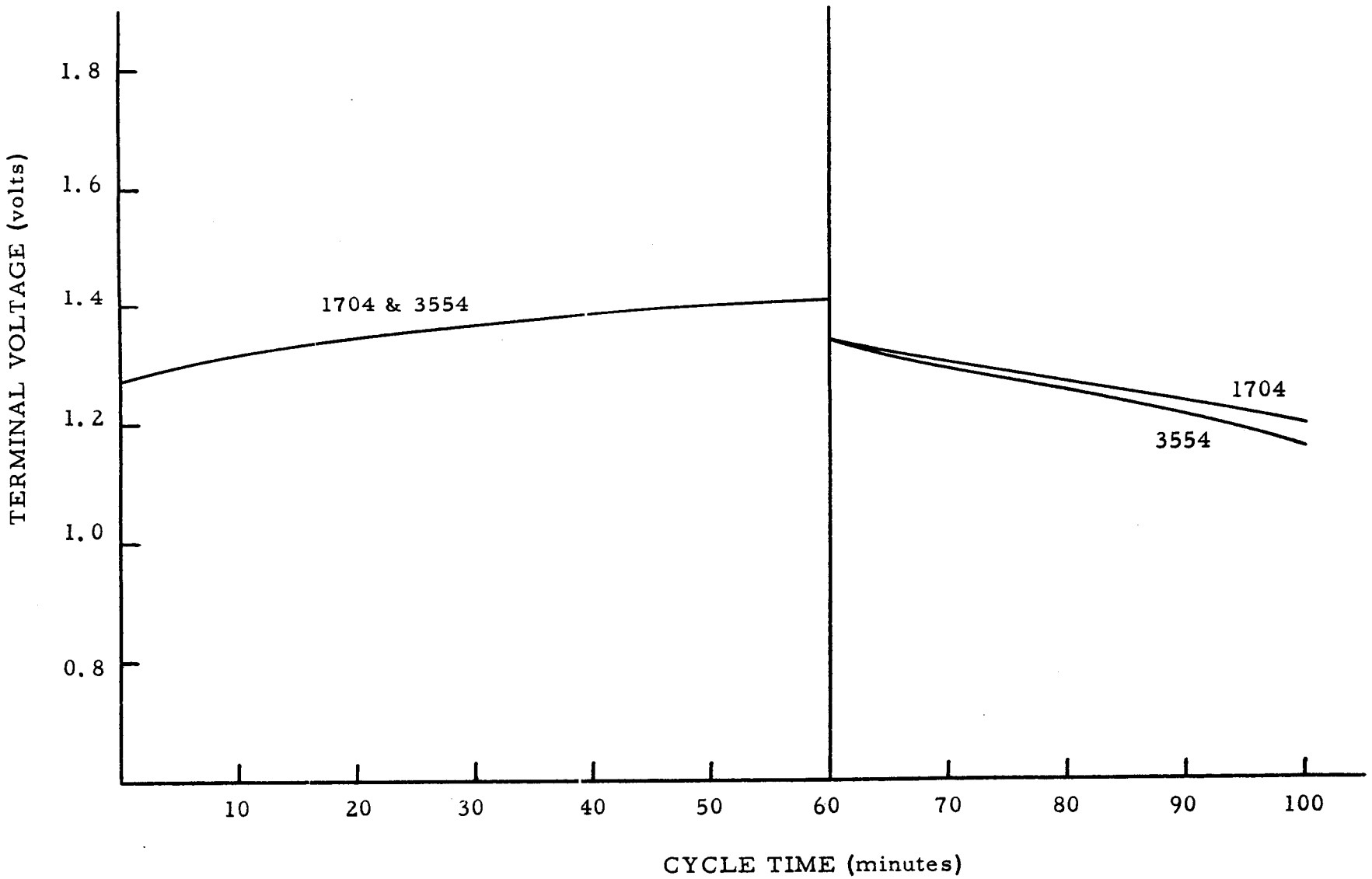


Figure 42 - Charge-Discharge Voltage Characteristics - Cell #3
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

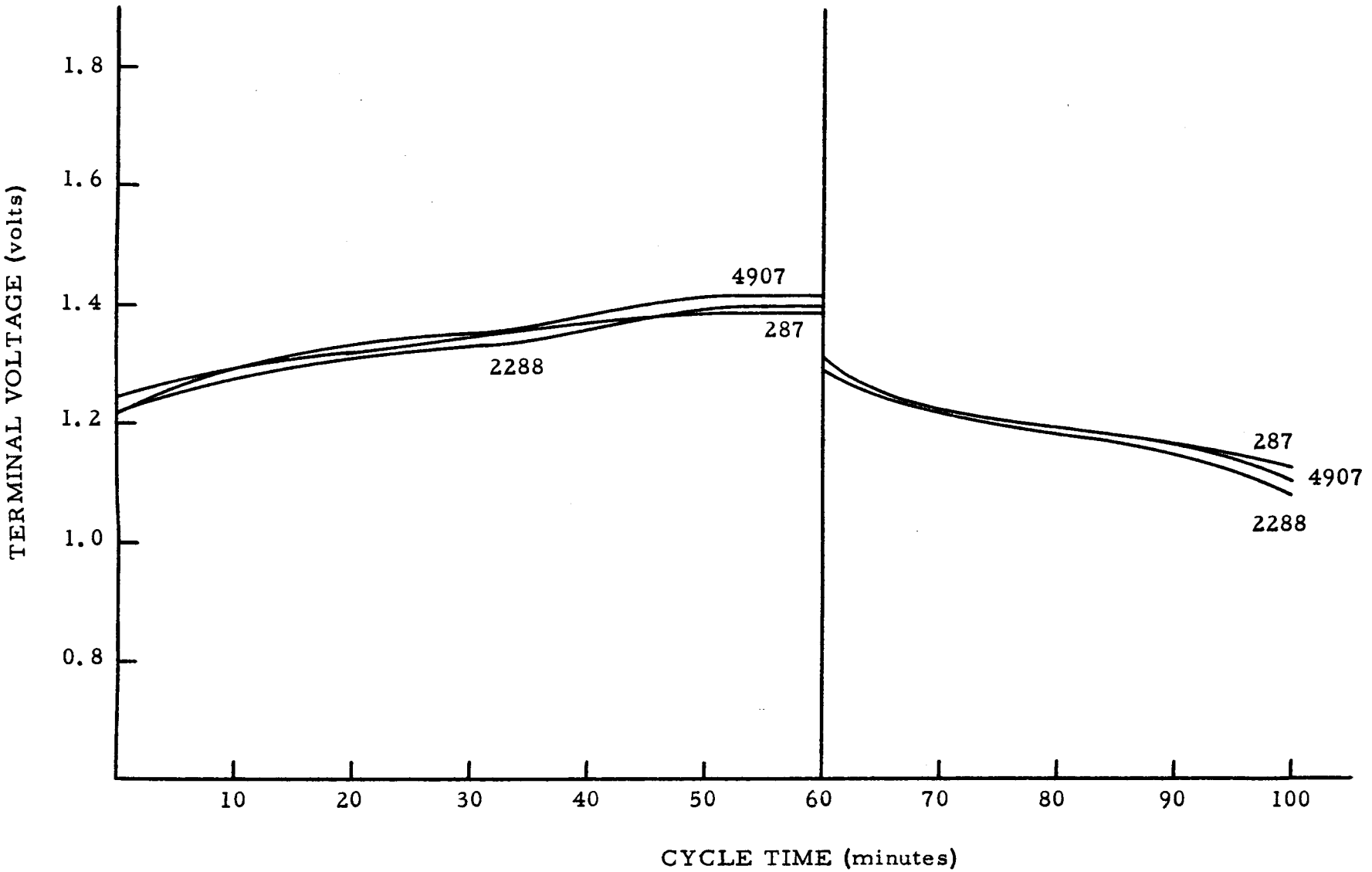


Figure 43 - Charge-Discharge Voltage Characteristics - Cell #13
Cycle Life: 25% Discharge at 25°C
Gould-National Cell

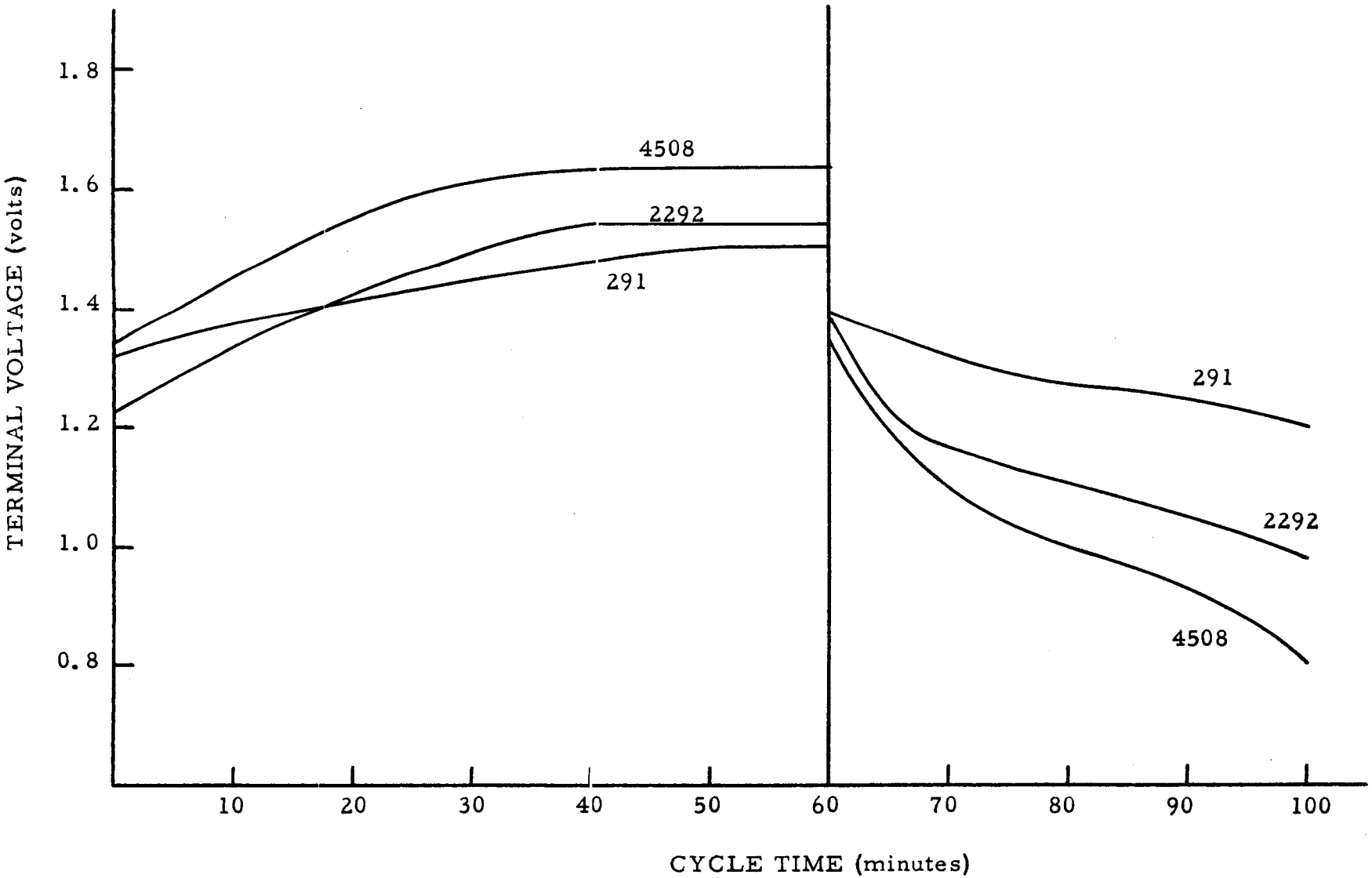


Figure 44 - Charge-Discharge Voltage Characteristics - Cell #49
Cycle Life: 40% Discharge at 25°C
Gould-National Cell

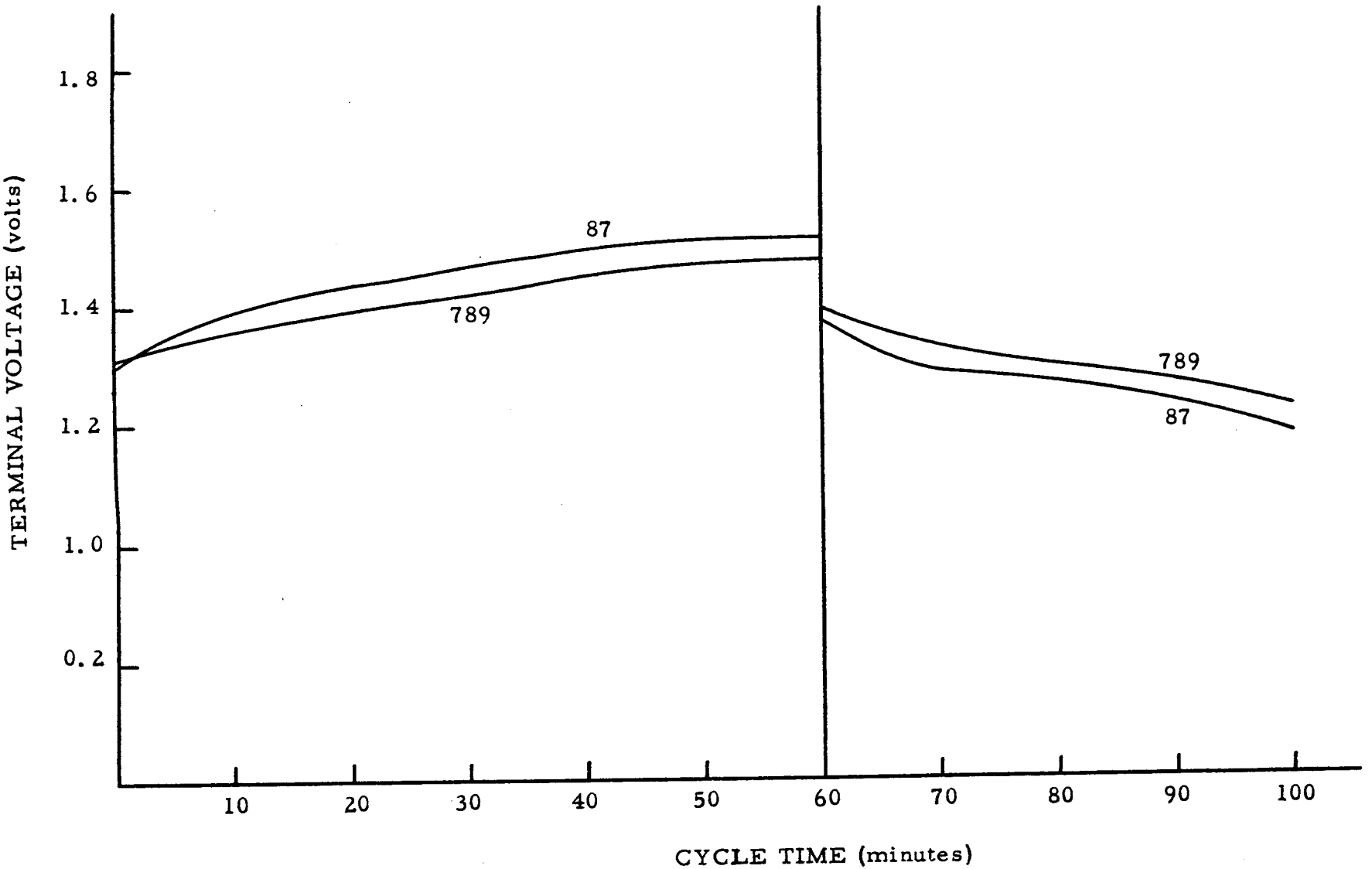


Figure 45 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at -10°C
Gulton Cells

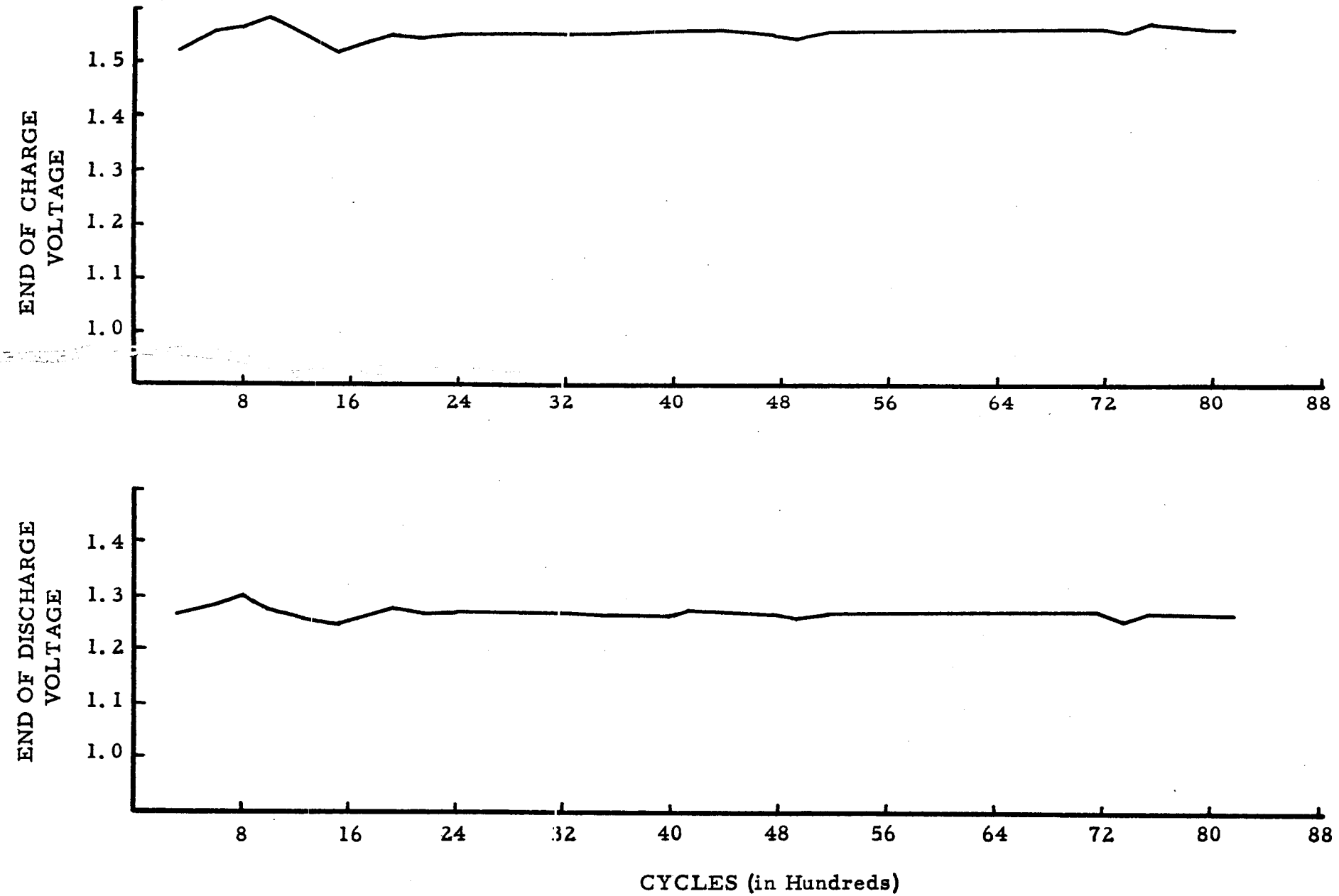


Figure 46 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 25°C
Gulton Cells

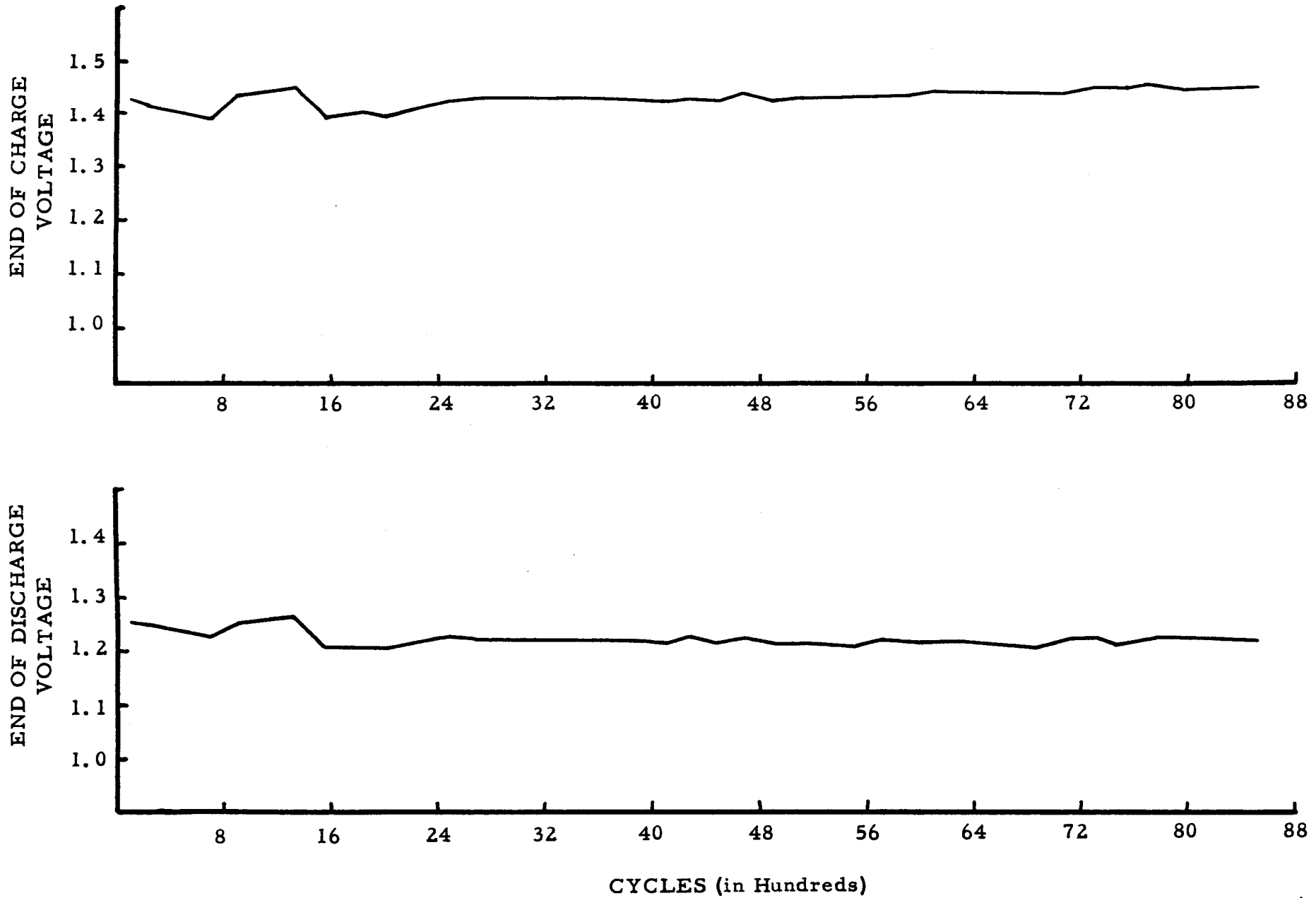


Figure 47 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 10% Discharge at 50°C
Gultor Cells

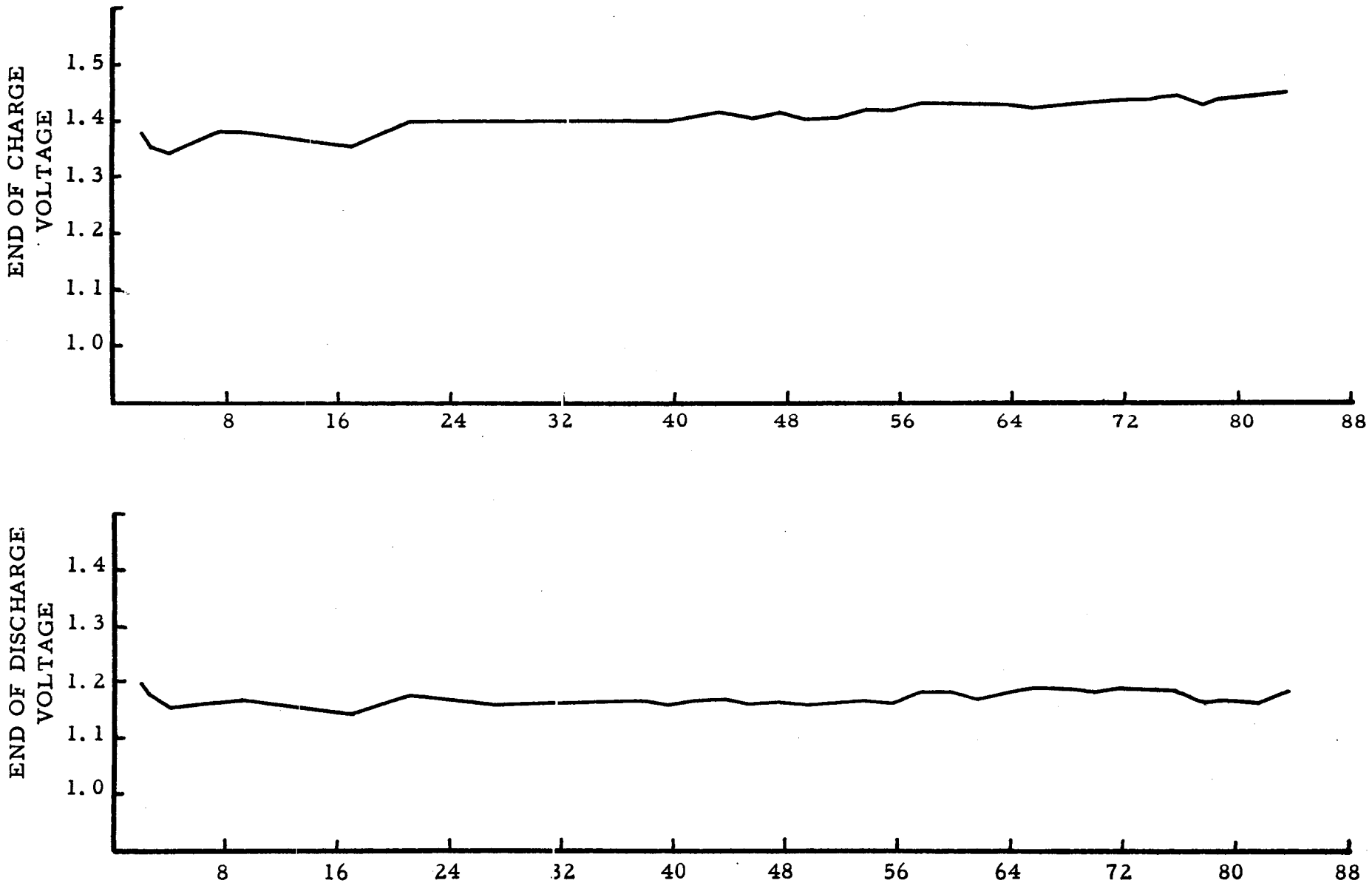


Figure 48 - Endpoint Voltage Characteristics - Group Average
Cycle Life: 25% Discharge at 25°C
Gulton Cells

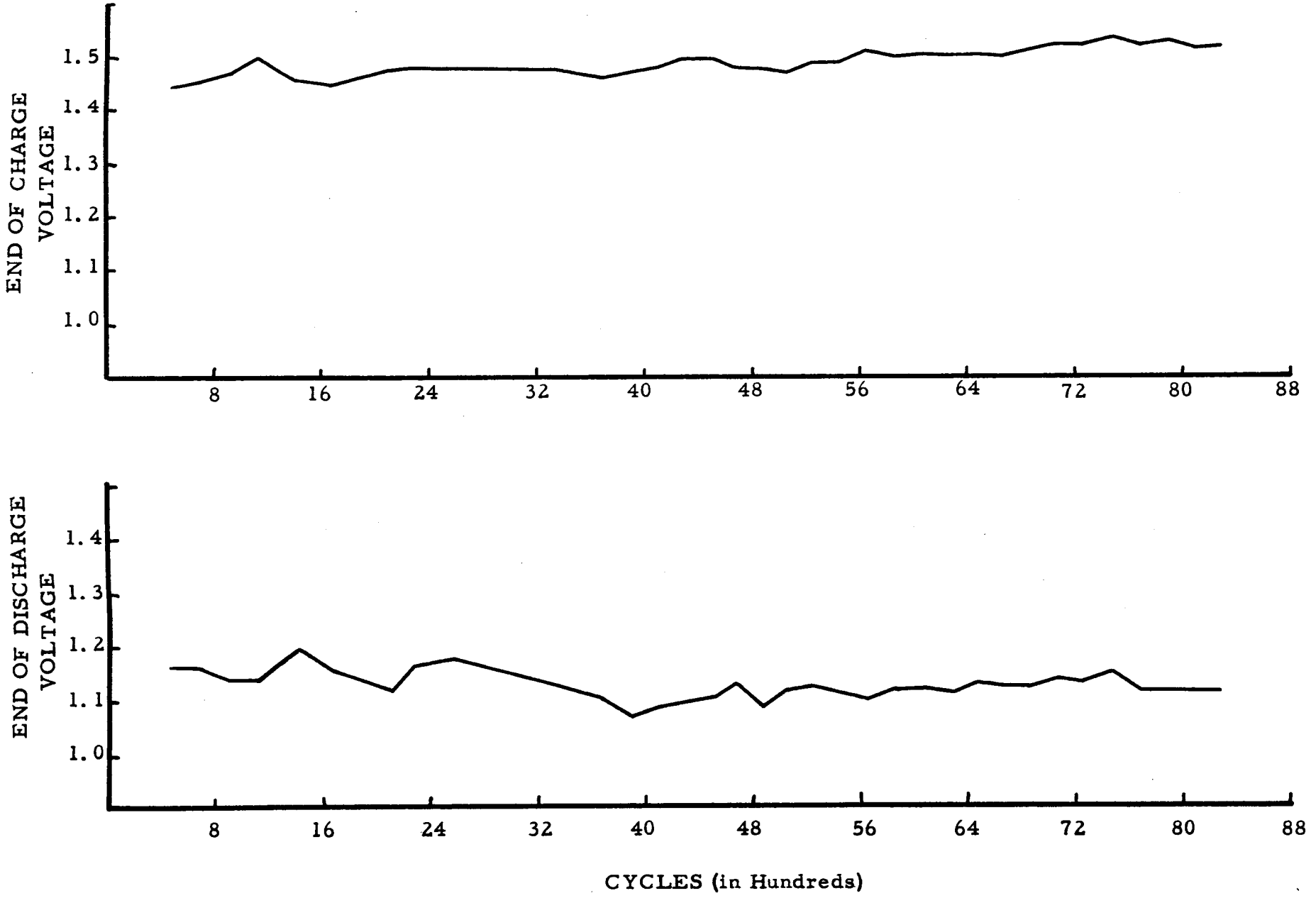


Figure 49 - Endpoint Voltage Characteristics - Cell #620
Cycle Life: 10% Discharge at -10°C
Gulton Cell

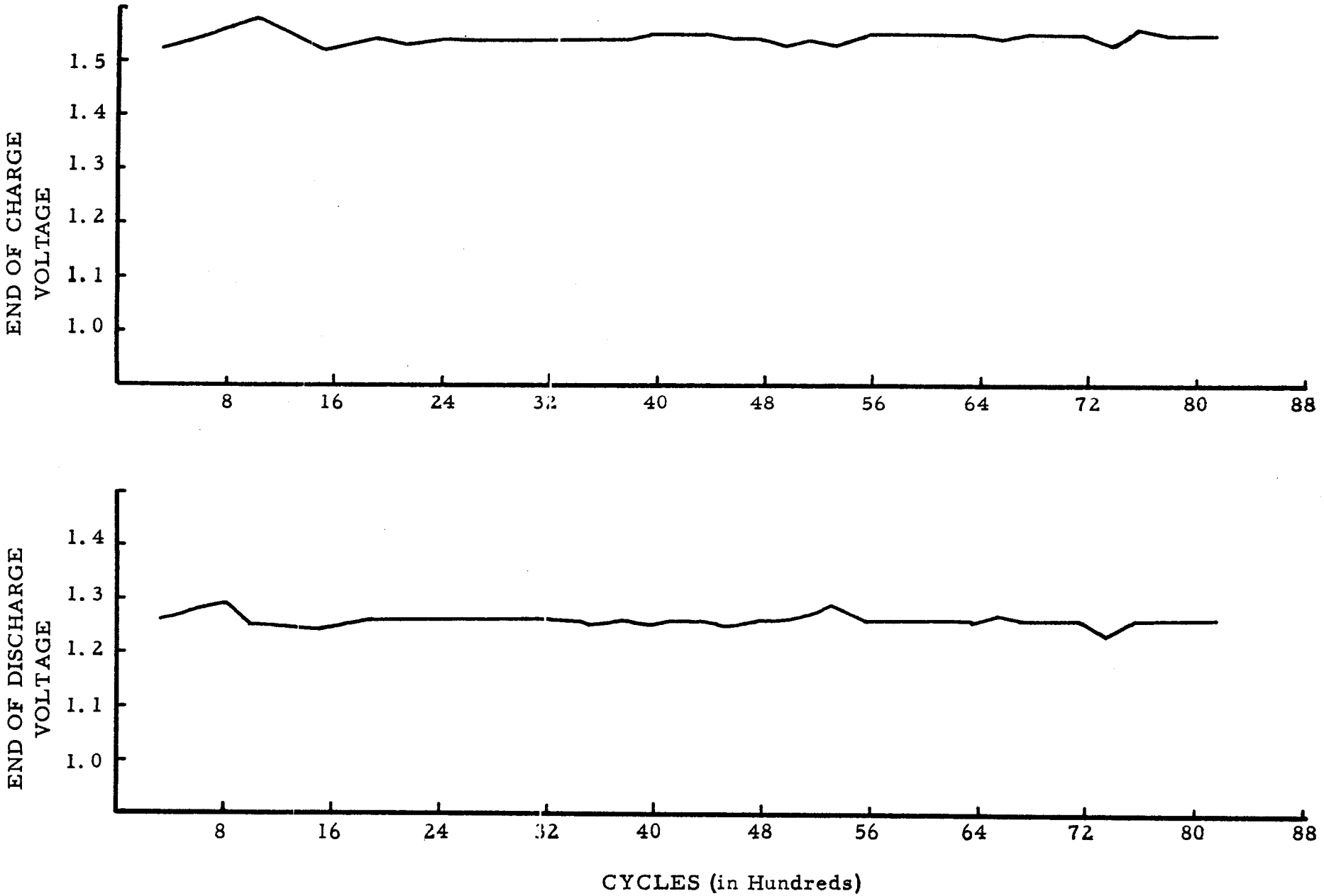


Figure 50 - Endpoint Voltage Characteristics - Cell #783
Cycle Life: 10% Discharge at -10°C
Gulton Cell

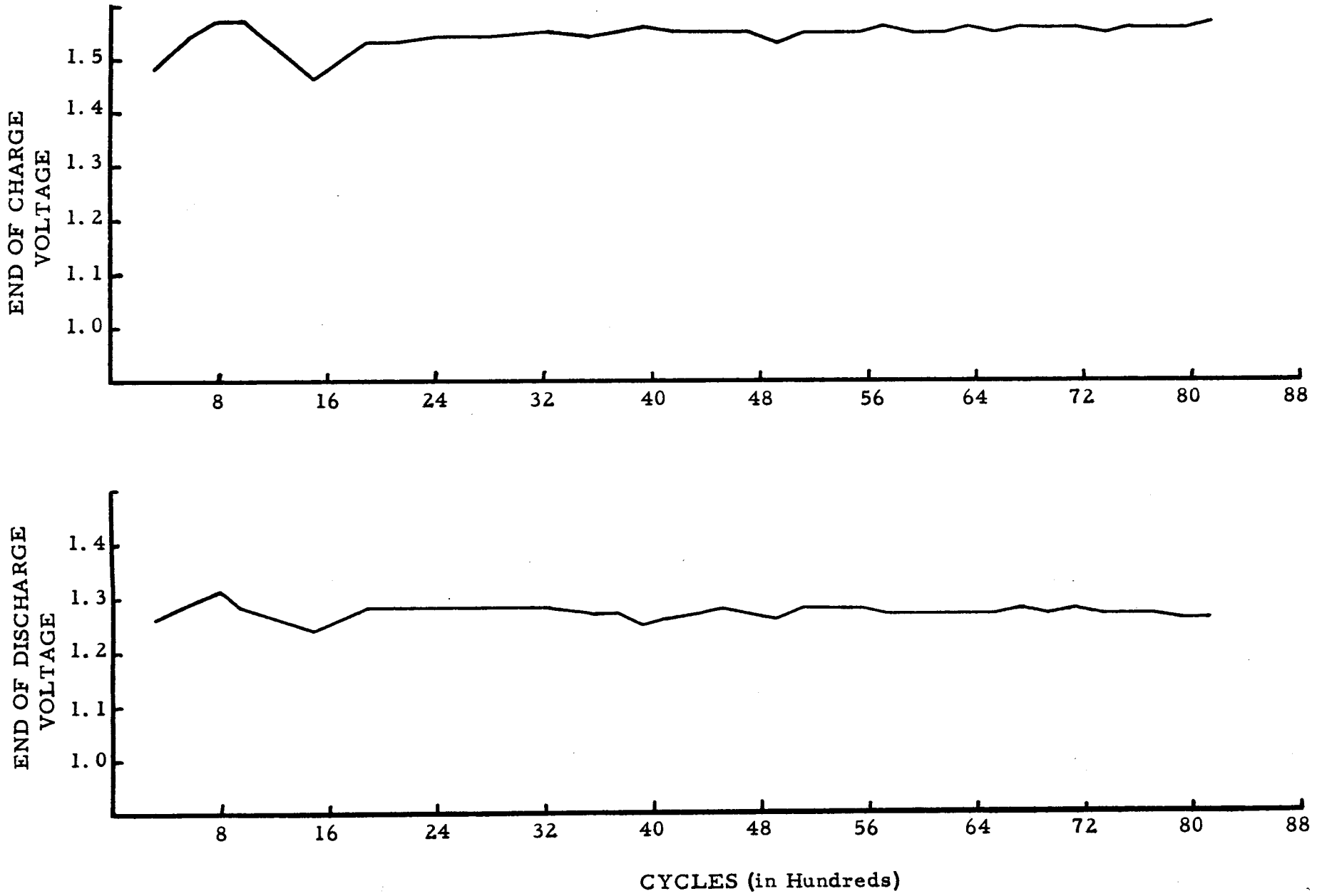


Figure 51 - Endpoint Voltage Characteristics - Cell #638
Cycle Life: 10% Discharge at 25°C.
Gulton Cell

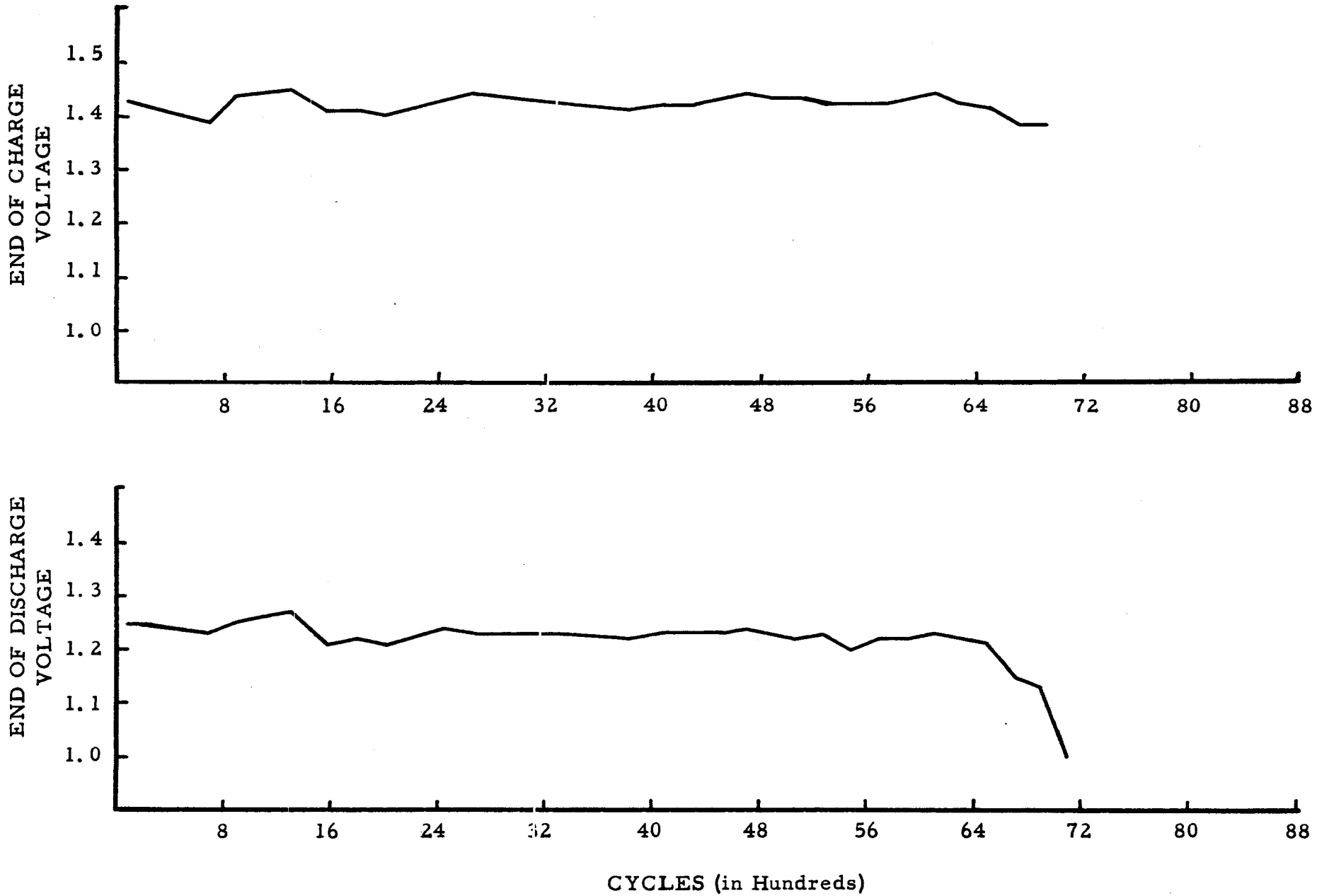


Figure 52 - Endpoint Voltage Characteristics - Cell #822
Cycle Life: 10% Discharge at 25°C
Gulton Cell

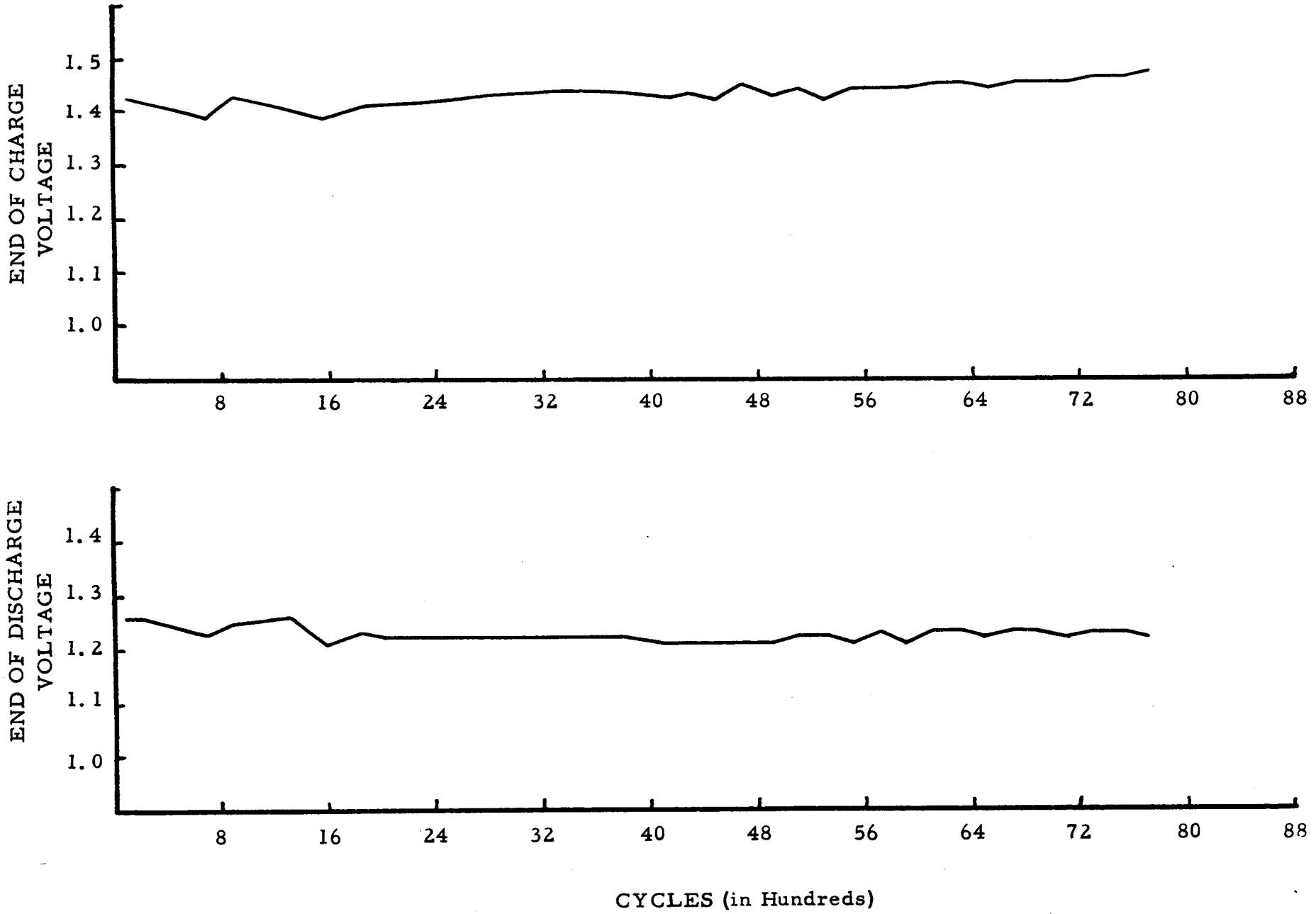


Figure 53 - Endpoint Voltage Characteristics - Cell #610
Cycle Life: 10% Discharge at 50°C
Gulton Cell

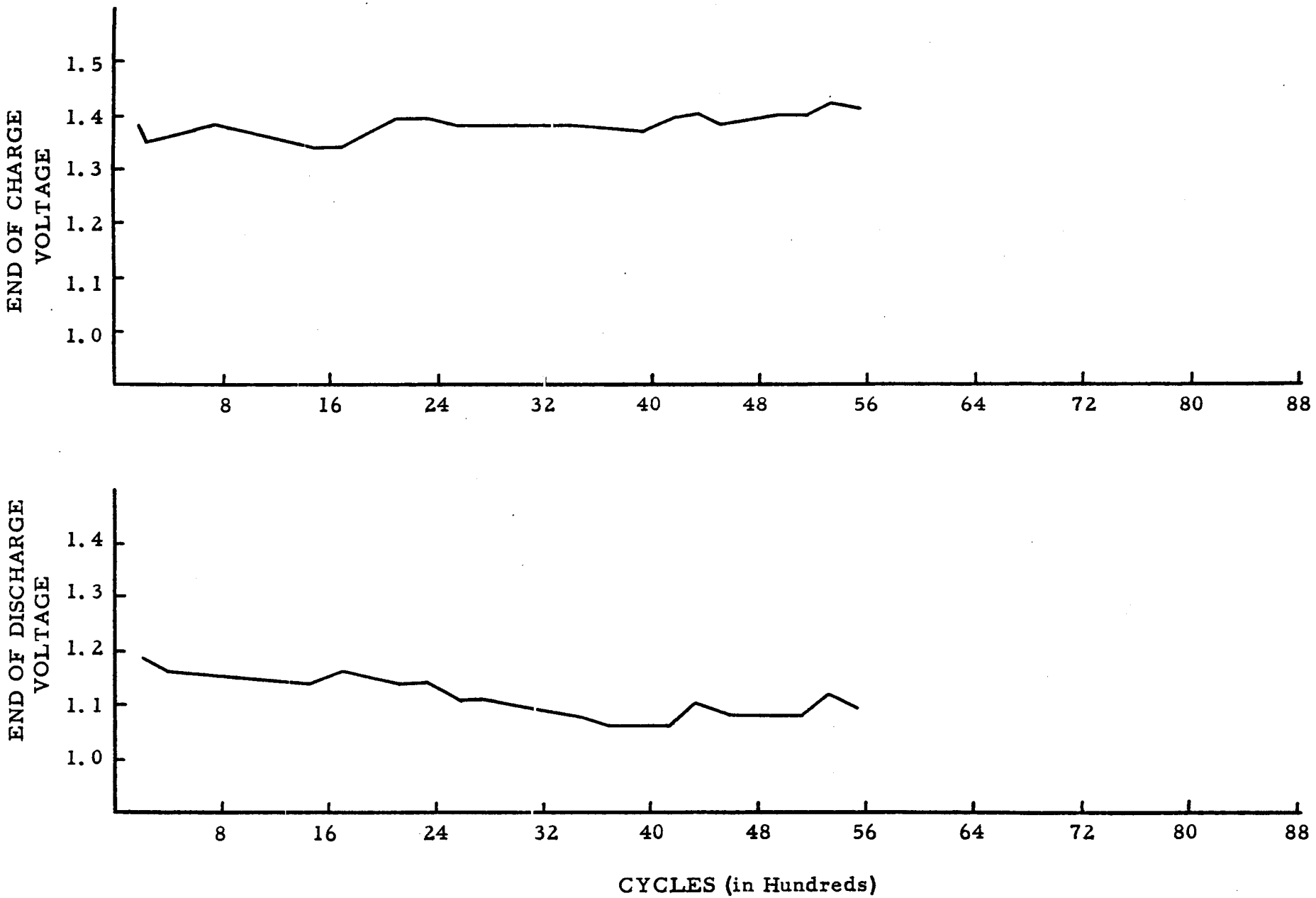


Figure 54 - Endpoint Voltage Characteristics - Cell #779
Cycle Life: 10% Discharge at 50°C
Gulton Cell

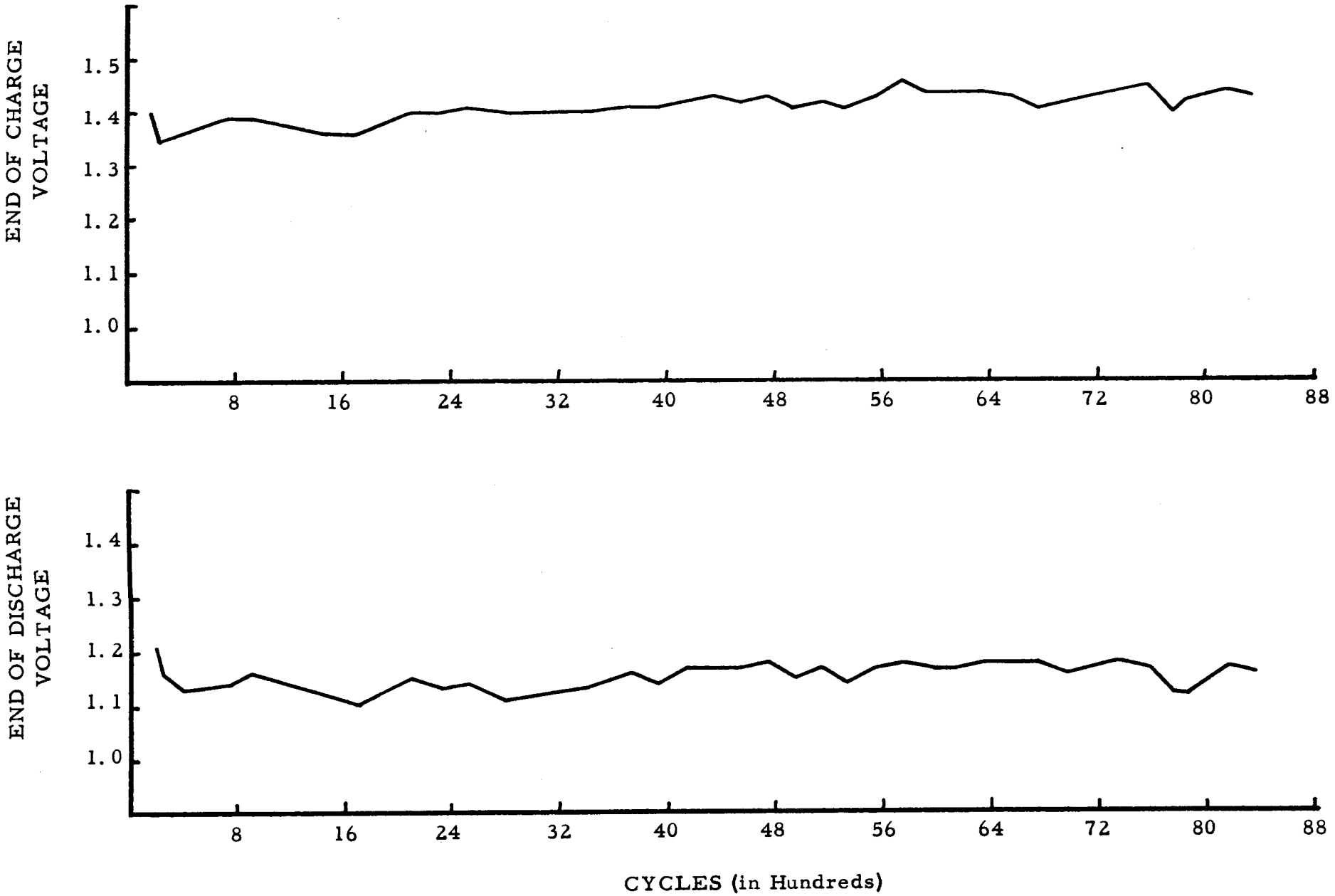


Figure 55 - Endpoint Voltage Characteristics - Cell #660
Cycle Life: 25% Discharge at 25°C
Gulton Cell

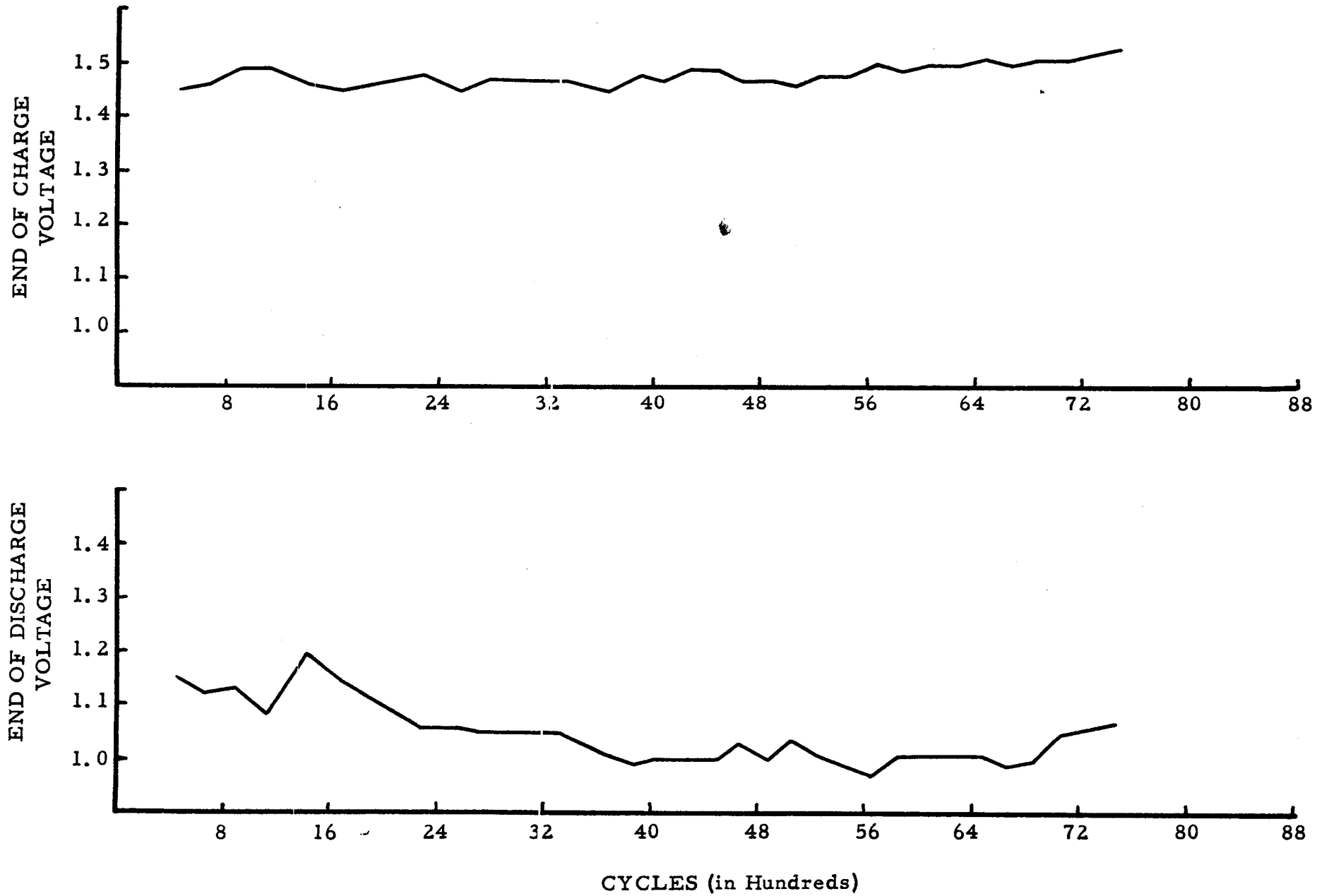


Figure 56 - Endpoint Voltage Characteristics - Cell #816
Cycle Life: 25% Discharge at 25°C
Gulton Cell

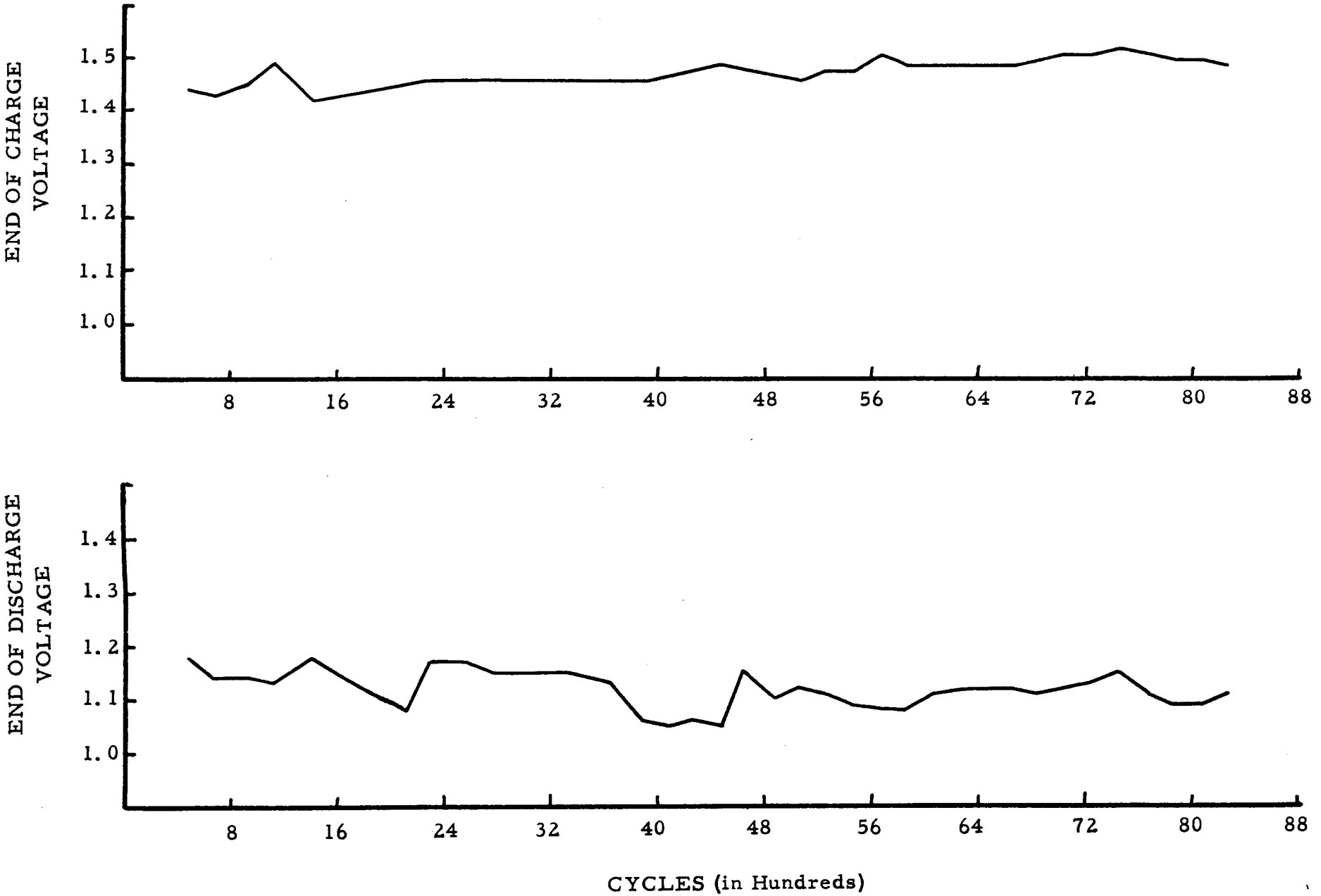


Figure 57 - Charge-Discharge Voltage Characteristics - Cell #620
Cycle Life: 10% Discharge at -10°C
Gulton Cell

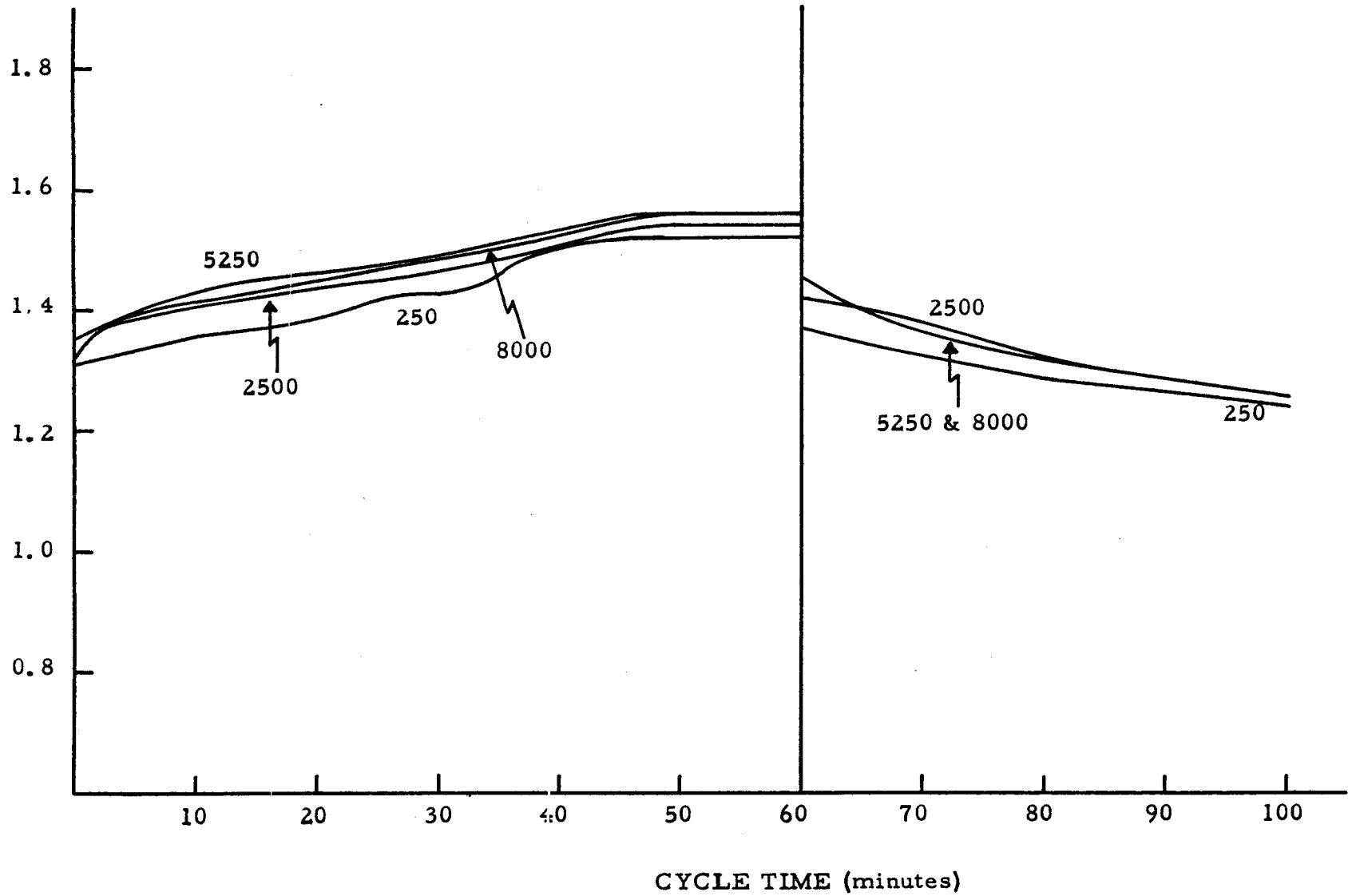


Figure 58 - Charge-Discharge Voltage Characteristics - Cell #783
Cycle Life: 10% Discharge at -10°C
Gulton Cell

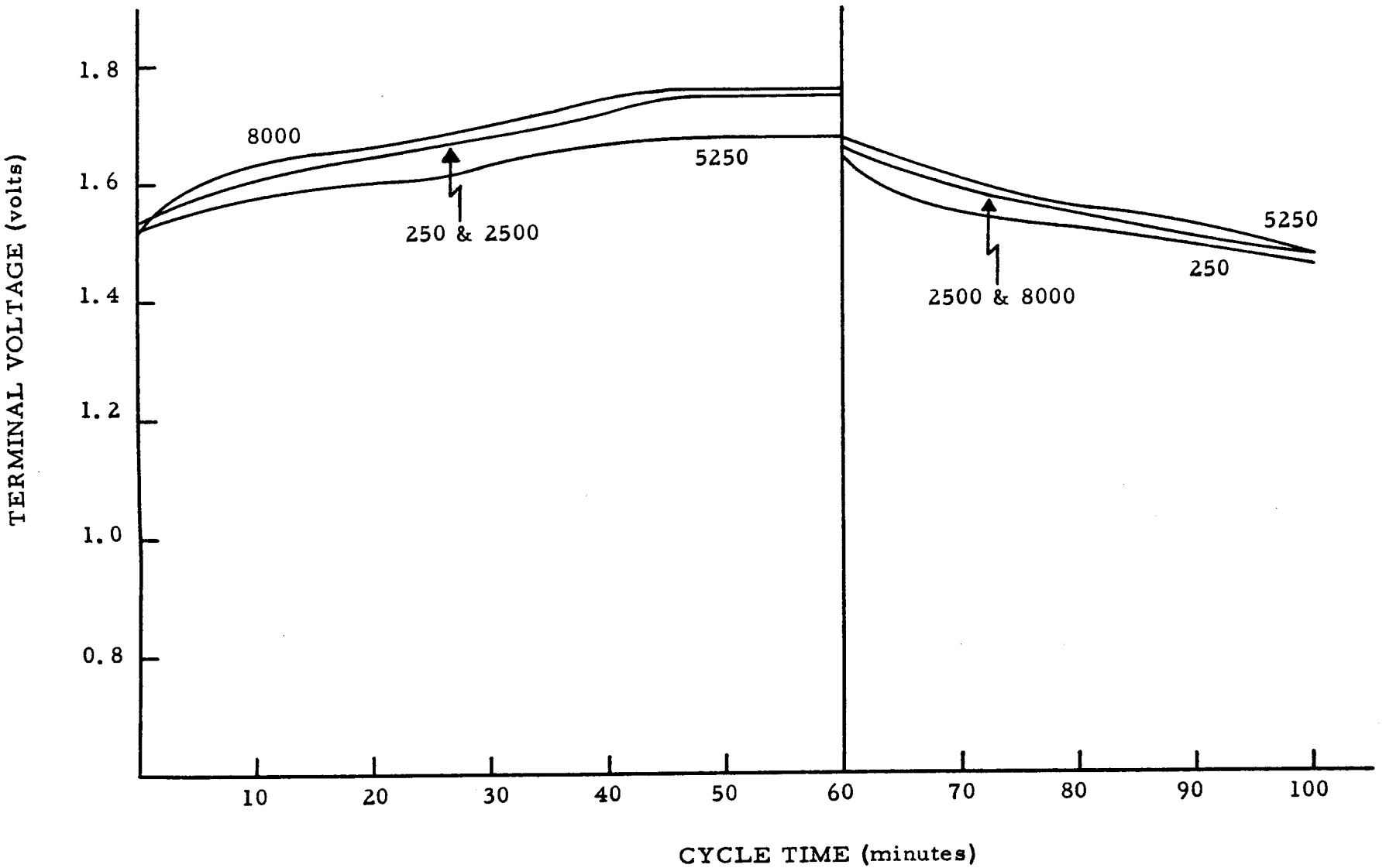


Figure 59 - Charge-Discharge Voltage Characteristics - Cell #638
Cycle Life: 10% Discharge at 25°C
Gulton Cell

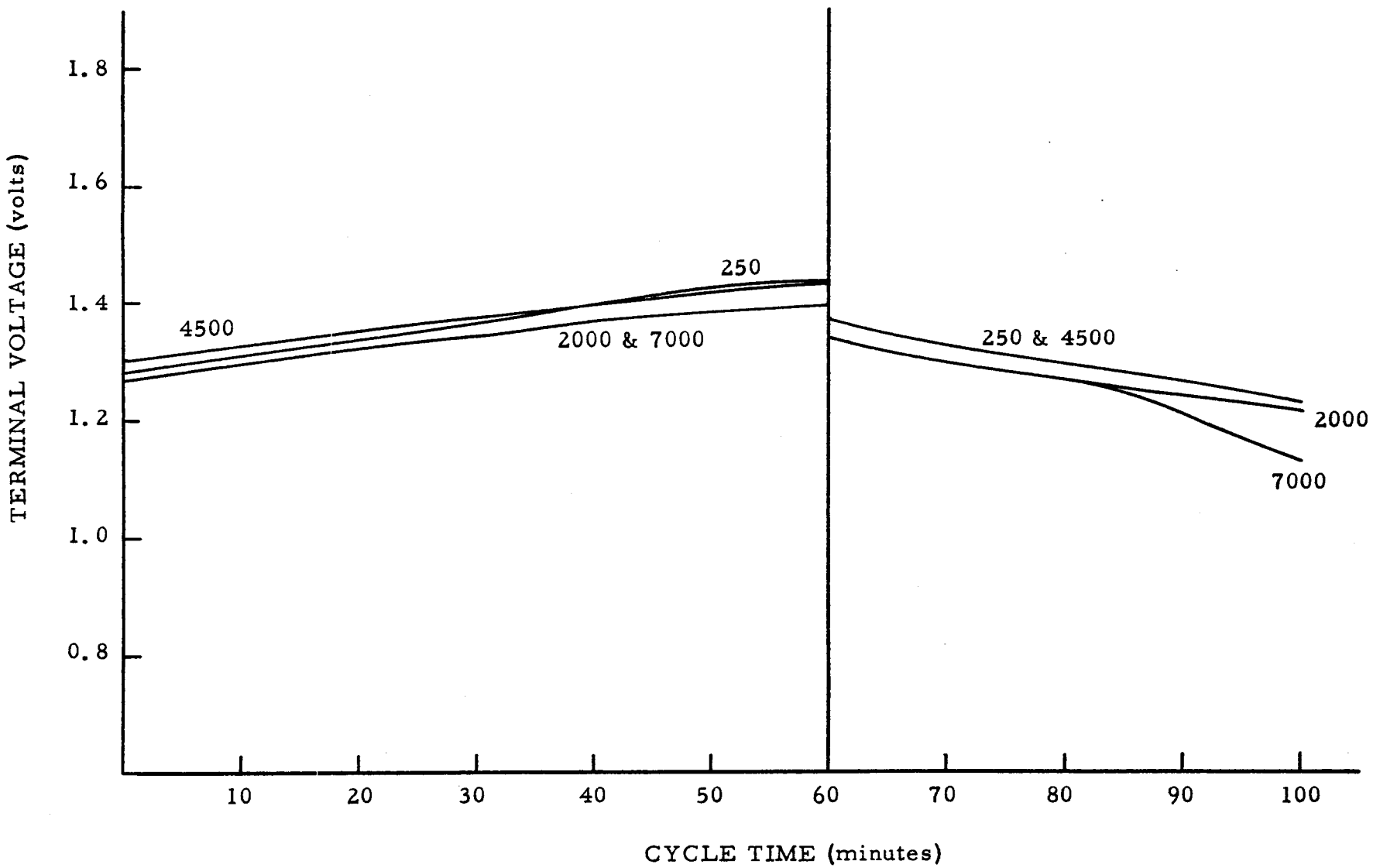


Figure 60 - Charge-Discharge Voltage Characteristics - Cell #823
Cycle Life: 10% Discharge at 25°C
Gulton Cell

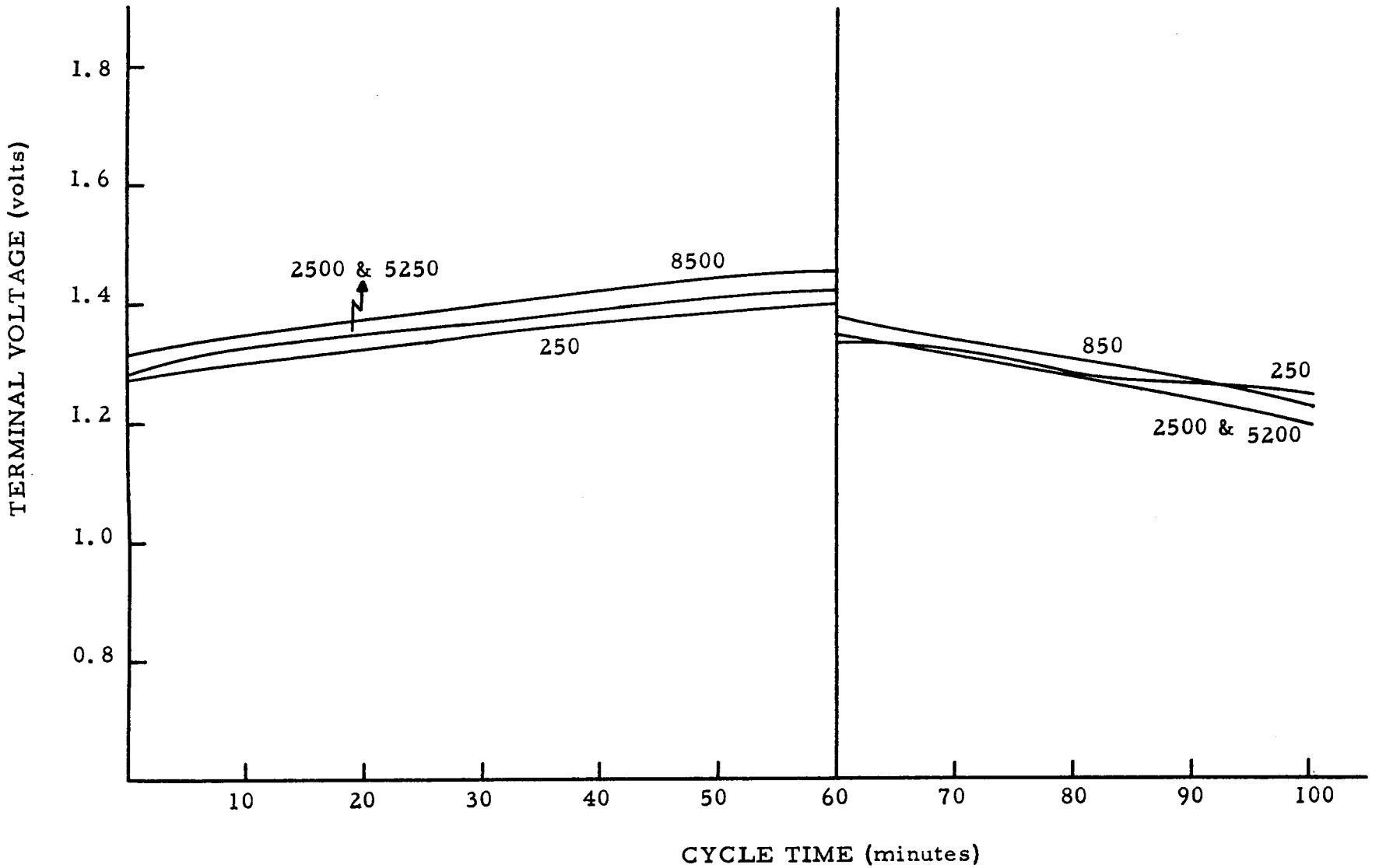


Figure 61 - Charge-Discharge Voltage Charateristics - Cell #610
Cycle Life: 10% Discharge at 50°C
Gulton Cell

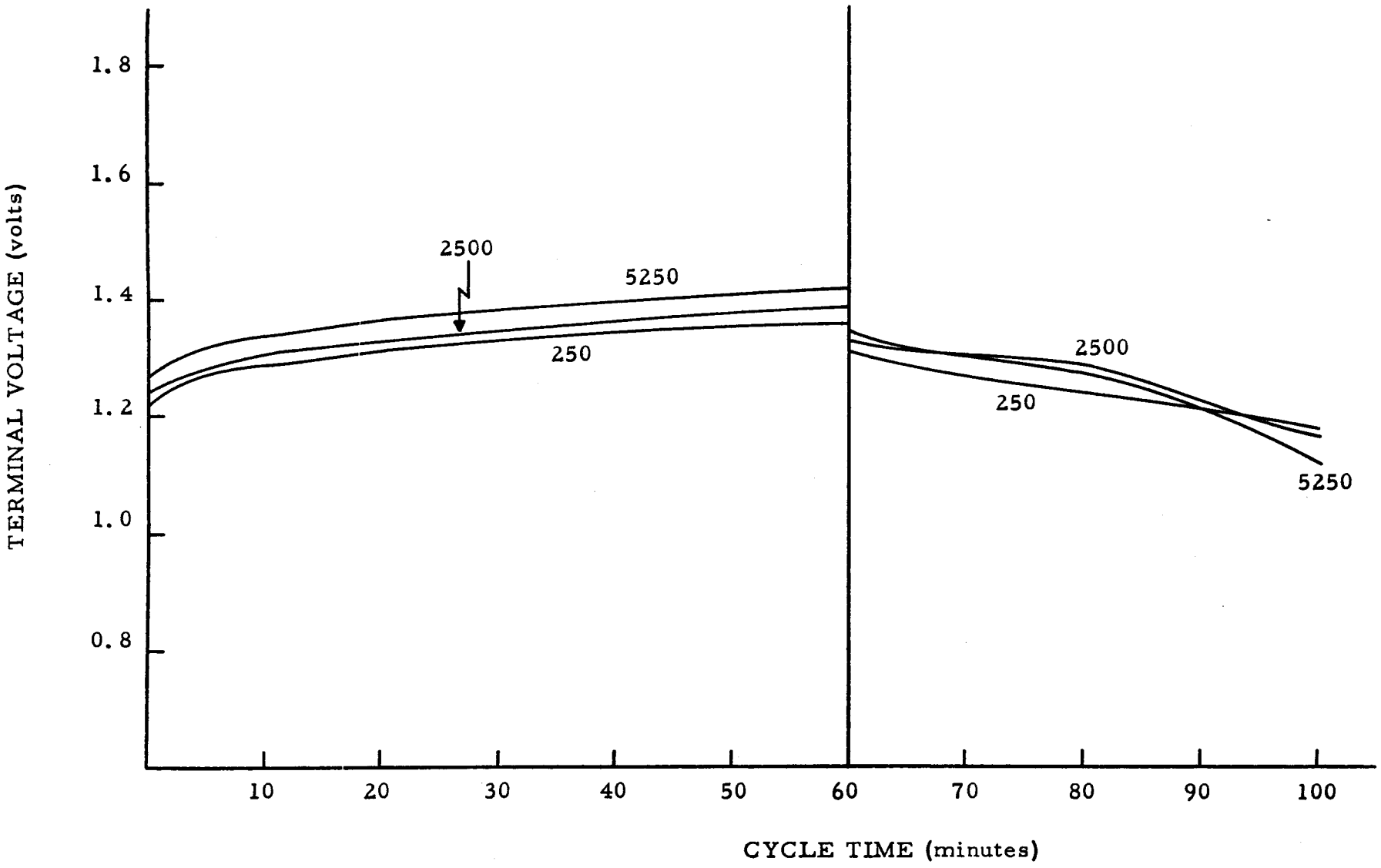


Figure 62 - Charge-Discharge Voltage Characteristics - Cell #779
Cycle Life: 10% Discharge at 50°C
Gulton Cell

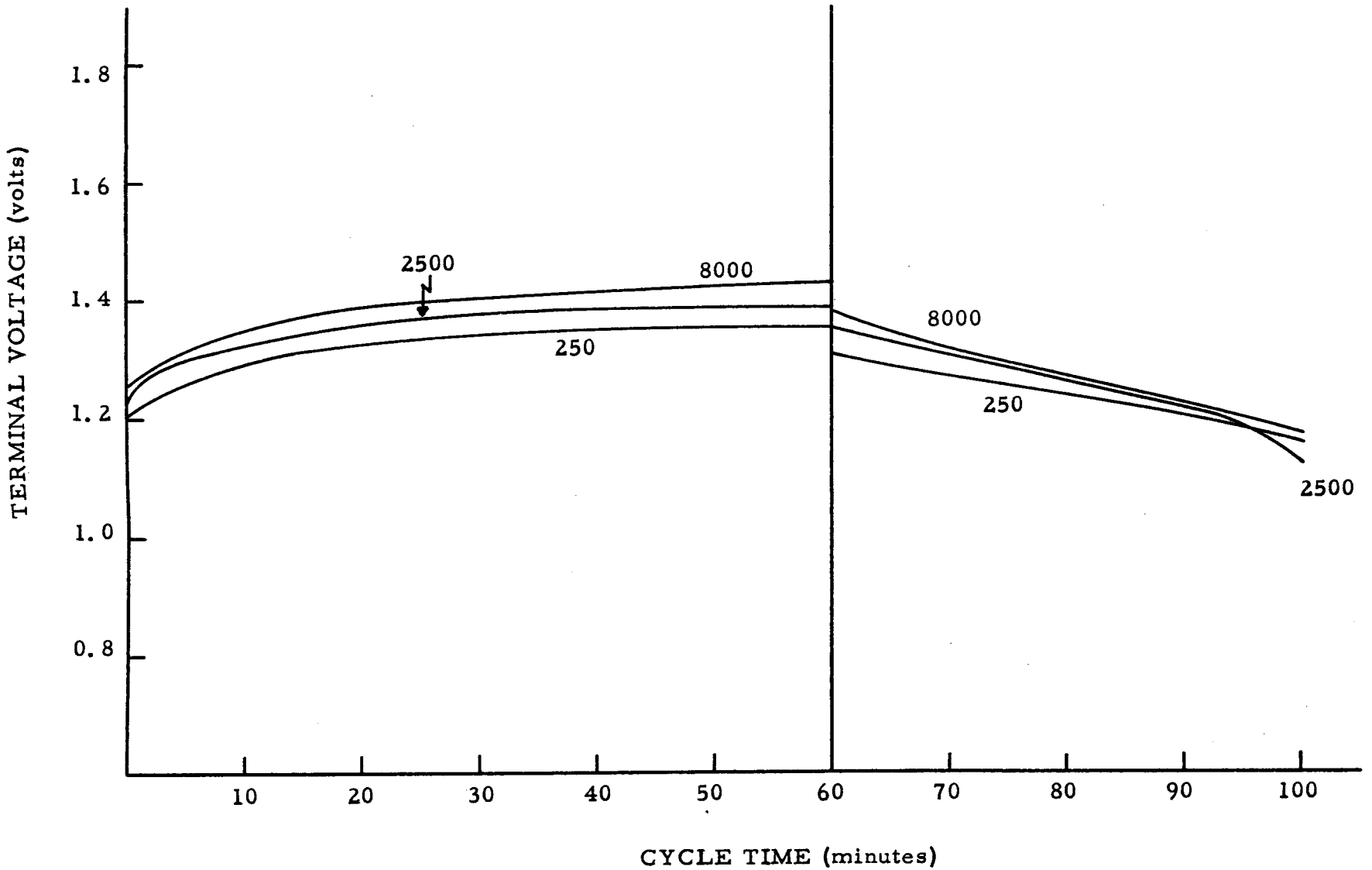


Figure 63 - Charge-Discharge Voltage Characteristics - Cell #660
Cycle Life: 25% Discharge at 25°C
Gulton Cell

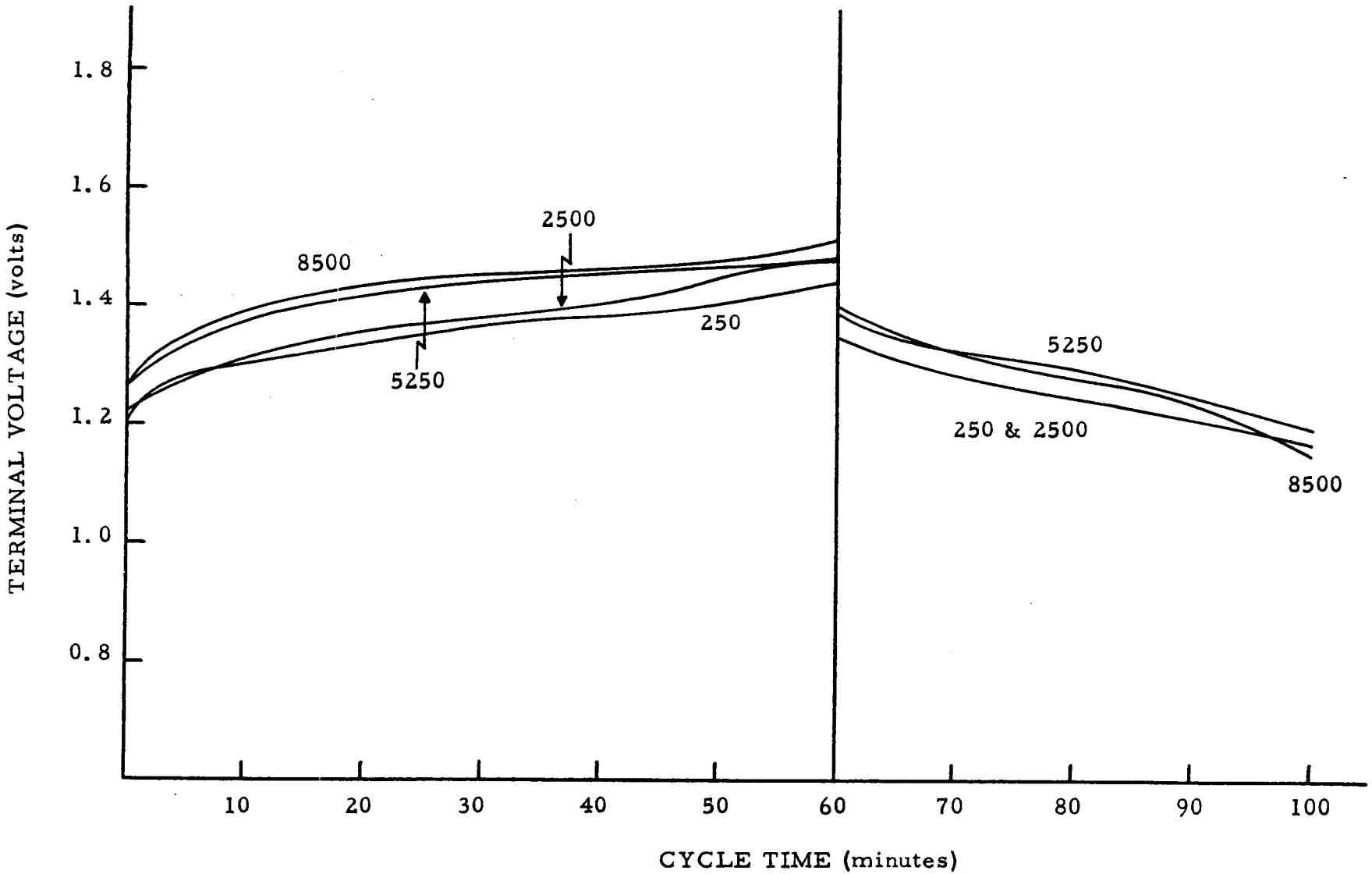


Figure 64 - Charge-Discharge Voltage Characteristics - Cell #816
Cycle Life: 25% Discharge at 25°C
Gulton Cell